



PAVER

Precision AgriVoltaics for Carbon Neutrality Enhanced Production and Reduced Environmental Impact in Greenhouse

Section 2



Thematic Area: Farming Systems
Budget: 790,100,00 €
Duration: 36 months
Project website: <https://jlloret.webs.upv.es/paver/>

State and Coordinator entity:
SPAIN,
Universitat Politècnica de Valencia (UPV)

Coordinator:
Jaime, Lloret.
Email jlloret@dcom.upv.es

Other in Consortium:
Universidad Politécnica de Cartagena, (UPTC) – SPAIN; Institut National de la Recherche Agronomique Morocco, (INRAM) – MOROCCO; University Sultan Moulay Slimane, (USMS) – MOROCCO; STE REOWA sarl, (REOWA) – MOROCCO; Green Power for Agriculture and Irrigation, (GPAI) – EGYPT; University Haute-Alsace, (UHA) – FRANCE;

1 Problem statement and key objectives

The increasing need for sustainable agriculture and renewable energy solutions has driven innovations in integrating photovoltaic systems with agricultural practices. Traditional greenhouses often rely on external energy sources, contributing to higher carbon footprints and operational costs. Moreover, resource efficiency—particularly water and nutrients—is a pressing concern amidst climate change and resource scarcity. There is a growing demand to develop environmentally friendly, economically viable, and technologically advanced systems that can enhance productivity while minimizing environmental impacts.

This project aims to address these challenges by advancing the adoption of agrivoltaic systems—integrating solar energy harvesting with crop production—specifically within cascade hydroponic greenhouses. The core problem lies in balancing energy generation, water use, and crop productivity to achieve sustainable, self-sufficient units capable of reducing greenhouse gas emissions and optimizing resource utilization.

Main Objectives:

- **Boost Adoption of Solar Agrivoltaics.** Promote the implementation of photovoltaic systems combined with hydroponic greenhouses to reach carbon neutrality in food production. This involves developing cost-effective, plug-and-play hardware and software solutions for energy management.
- **Develop and Test Digital Twin Technologies.** Create a real-time digital replica of the greenhouse environment to monitor and optimize crop growth, resource use, and energy consumption. This enables proactive decision-making and efficient management tailored to specific crops and conditions.
- **Innovate AIoT Monitoring Systems.** Design low-cost, integrated sensors and actuators specifically for cascade hydroponic greenhouses with solar energy harvesting. These systems will support precision agriculture by facilitating optimal water and nutrient management through data-driven insights.
- **Enhance Resource Efficiency and Water Recycling.** Implement water circular economy models by reusing water and nutrients within the system to maximize land productivity, reduce inputs, and lower costs. Such practices contribute to environmentally sustainable food production systems.
- **Evaluate and Optimize Energy Use and Business Models** Quantify the environmental benefits, such as CO₂ footprint reduction, and examine new business models for utilizing excess renewable energy locally, including potential applications like water desalination or other value-added products.

By integrating innovative agrivoltaic systems, digitalization, and resource-efficient practices, the project intends to create scalable solutions that support sustainable agriculture, reduce environmental impact, and promote technological transfer to farmers and industry stakeholders.

2 Brief summary of the methodology

1. The approach begins with an extensive review of current advances in agrivoltaic greenhouse infrastructure, identifying technological options, performance indicators, and challenges specific to the Mediterranean context. Based on this, optimal crops and configurations are selected, considering factors such as light needs, growth rates, and resilience.
2. A prototype smart agrivoltaic greenhouse is then developed, integrating photovoltaic panels that minimally impact crop growth while supplying energy for operations. A network of IoT sensors monitors environmental variables—temperature, humidity, solar radiation, water levels, and crop health—feeding real-time data into a Digital Twin model, a dynamic digital replica that enables continuous diagnostics and optimization.
3. Simulations within the Digital Twin assess different photovoltaic arrangements and operational strategies to evaluate effects on crop yield, resource efficiency, and carbon footprint reduction. Pilot testing validates system performance under controlled conditions, focusing on crop productivity, resource usage, and environmental sustainability, particularly the influence of solar panels on growth.
4. Data collected from these experiments is analyzed with machine learning techniques to identify key performance factors. The Digital Twin allows for real-time adjustments, optimizing productivity and resource utilization. This iterative process ensures system robustness, scalability, and efficiency.
5. Finally, results are documented through technical reports, academic publications, and farmer-oriented guides, complemented by workshops and dissemination activities aimed at promoting adoption among industry stakeholders and farmers. This rigorous methodology aims to develop sustainable, efficient, and scalable agrivoltaic greenhouse solutions powered by AIoT and Digital Twin technologies.

3 Key exploitable results

Key Exploitable Results (KERs)

KER 1: AI-Powered Irrigation and Energy Management Prototype (Software/Processes). The project will deliver a prototype that demonstrates how artificial intelligence can optimize irrigation and energy use in greenhouses. IoT sensors will monitor water, energy, and crop conditions in real time, while machine learning algorithms automatically adjust irrigation and energy parameters. This reduces operational costs, maximizes resource efficiency, and minimizes the carbon footprint of farming practices. Beyond its technological demonstration, the prototype will serve as an educational tool, showcasing the practical benefits of digitalisation in agriculture and fostering confidence in the adoption of smart solutions.

KER 2: Research Data Sets and Future Research Roadmap on Sustainable Agriculture (Data/Research Roadmaps). Validated data sets will be generated from the prototype and related project activities, documenting the performance of smart irrigation and renewable energy technologies across diverse contexts. These datasets will provide the basis for a research roadmap that identifies barriers, opportunities, and priorities for advancing sustainable farming systems. The roadmap will guide researchers, innovators, and policymakers in defining future directions for agricultural digitalisation, ensuring continuity of knowledge and strengthening the link between innovation and sustainability.

KER 3: Sustainable Agriculture Policy Briefs and Training Materials (Policy Recommendations/Briefs + Educational Materials). Building on the datasets and roadmap, the project will produce policy briefs offering evidence-based recommendations to integrate digital and renewable energy solutions into agricultural strategies. These briefs will support policymakers and public authorities in promoting efficient water and energy use, accelerating technology adoption, and reducing environmental impacts. At the same time, the project will develop training materials for farmers, technicians, and students, providing practical resources on renewable energy, irrigation efficiency, and equipment maintenance. By combining strategic policy guidance with hands-on training, this KER ensures that knowledge is effectively translated into both systemic change and real-world practices in Mediterranean farming systems.



This project is part of the PRIMA Programme supported by the European Union

PARTNERS



NATIONAL FUNDING AGENCIES

