Exploring Agrivoltaics in Viticulture: Opportunities for Southern Spain

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Introduction

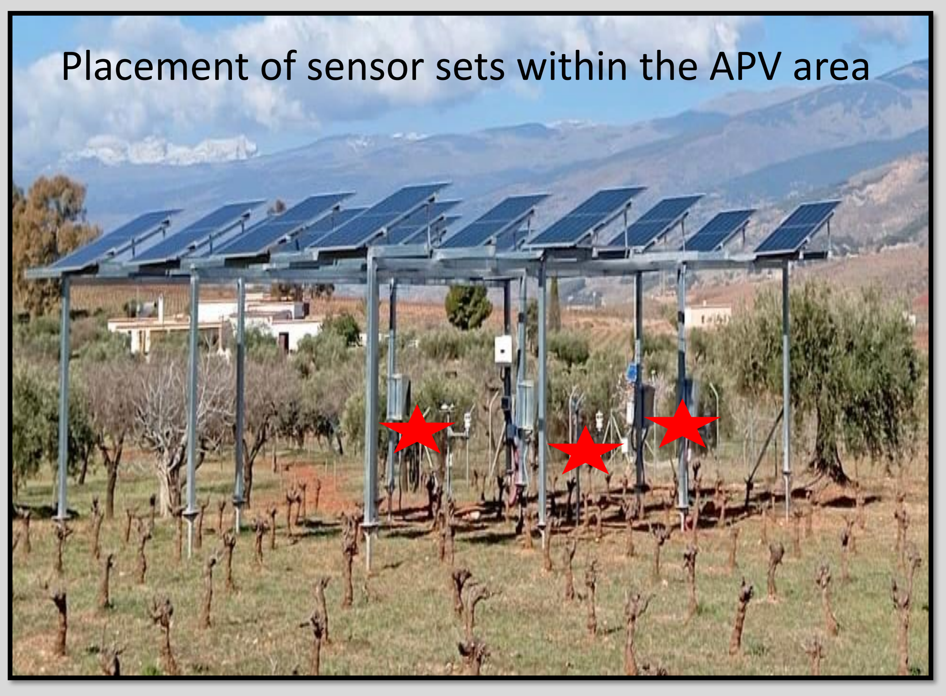
- DLR investigates the **synergies between PV technology and agriculture:**
  - Climate-resilient agriculture.
  - Decentralized energy transition.
- About **90% of traditional wine areas** in **southern Spain** are at **high risk of disappearing** in some decades because of climate change challenges:[1]
  - Longer drought periods.
  - More frequent heatwaves.
  - Extreme and more frequent hail events.
- This work presents the **southernmost agrivoltaic (APV)** installation in a **vineyard in Europe**.

Experimental Setup

- **Pioneering agrivoltaic (APV) pilot project** in Almería, southern Spain, located within an organic vineyard[1].
- **Overhead PV system** with a checkerboard layout, covering **120 m²** and shading 32 Merlot vines (Ground Coverage Ratio – GCR: **38%**).
- System classified as **Category I – Use 1A** under **DIN SPEC 91434 (Germany)**.
- **Eco-friendly foundation** using ground screws to **prevent soil compaction**.
- **PV capacity**: **10.8 kWp** from **18 modules. Inverter** of **10 kWn**.
- **Energy use**: Electricity is used **on-site for self-consumption** by the main winery building.

Monitoring System

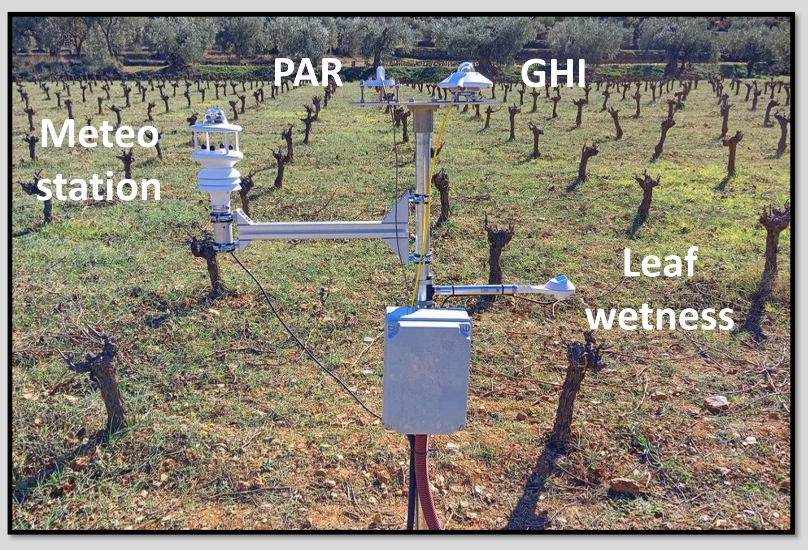
- **4 measurement zones** to assess the impact of shading on microclimate, soil and crop performance:
  - Under the PV structure (x3) → APV area
  - Control area (no shading)



- **Sensors** take measurements with 1-minute resolution

Category	Parameters Measured
Meteorological	• Air temperature • Relative humidity • Wind speed and direction • Precipitation
Irradiance	• Solar irradiance (PAR, GHI, G_{POA_f}, G_{POA_r})
Soil	• Soil temperature • Soil moisture
Crop	• Leaf wetness • Brix (sugar content) • Physiological traits • Yield quantity and quality

Instrumented mast in the control area with meteorological sensors, irradiance sensors (PAR and GHI), and a leaf wetness sensor.

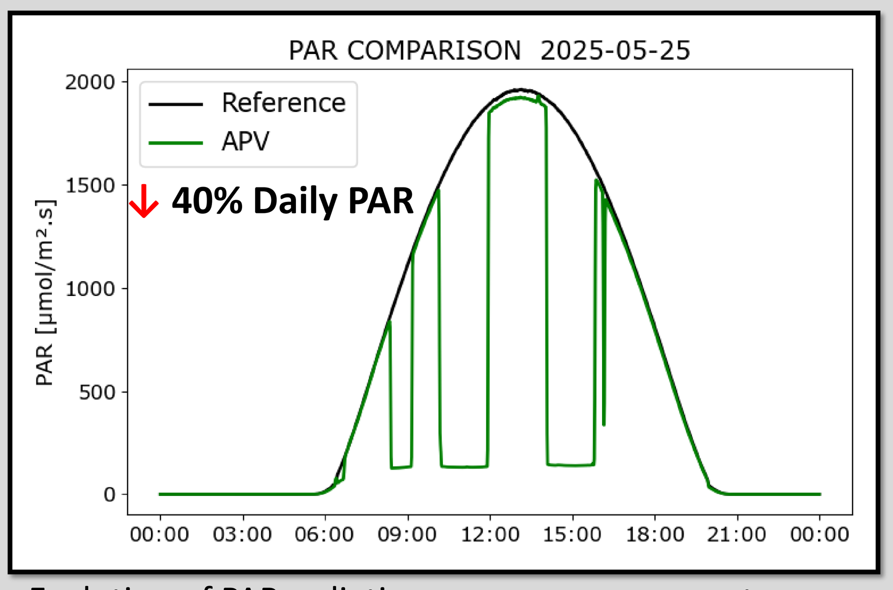


A drone picture of the APV setup in an eco-friendly vineyard[2], located in a valley surrounded by high mountains and fertile farmland with vineyards, olive trees, and almond trees. Top Right – A close-up of a grapevine growing under the APV structure. The system was installed in January 2025 on land owned by Cortijo El Cura – Ecobodega[3].

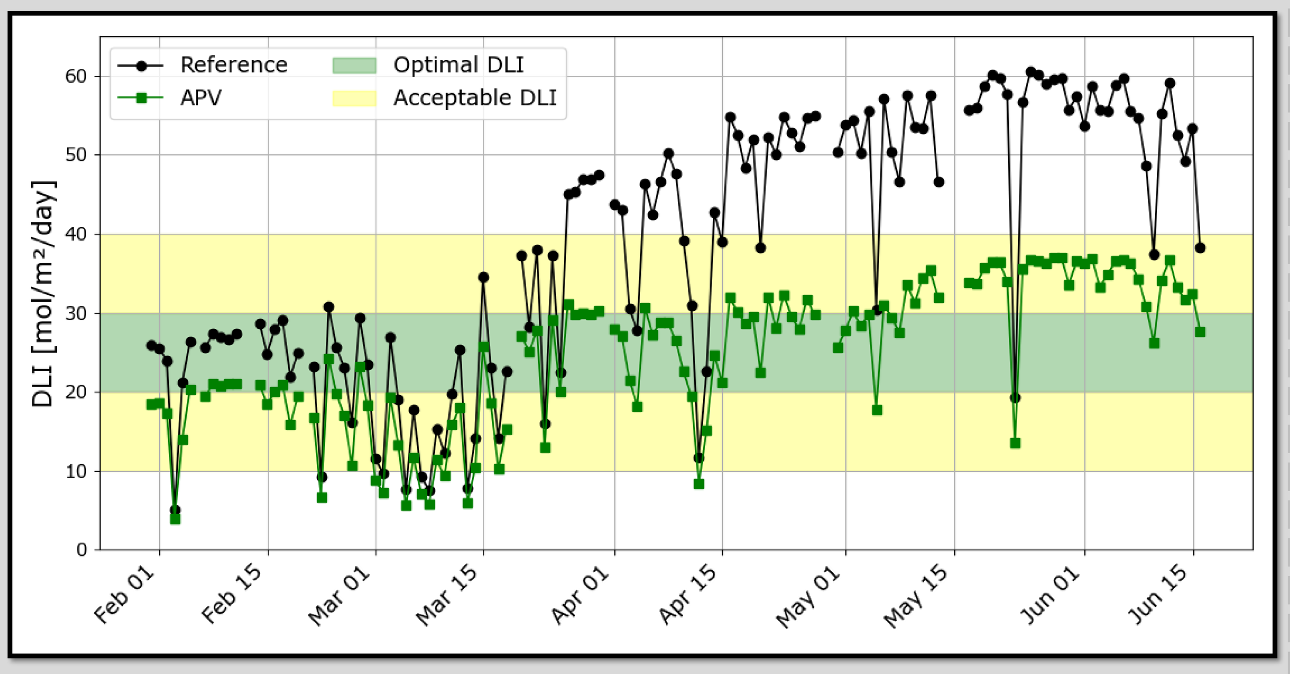
Results

Irradiance pattern

- Optimal Daily Light Integral (DLI) values for grapevine cultivation range between 20 and 30 mol m^{-2} d^{-1} depending on the development stage and on other weather conditions[4].
- Measurements by EKO ML-020P PAR sensors at 1.5 m height to monitor DLI values.
- The checkerboard layout allows mitigating the excess of radiation during the hours with PAR values higher that the saturation point for grapevines, which is around 1200 µmol m^{-2}·s^{-1}.[5]
- Excepting on very cloudy days→ DLI > 20 mol m^{-2} d^{-1} below the panels and in the control zone.
- DLI increases toward the summer, reaching nearly 40 mol m^{-2} d^{-1} in the APV area.
- Near the summer solstice, DLI in the APV area is about 40% lower than in the control area → only slightly higher than the optimal values.

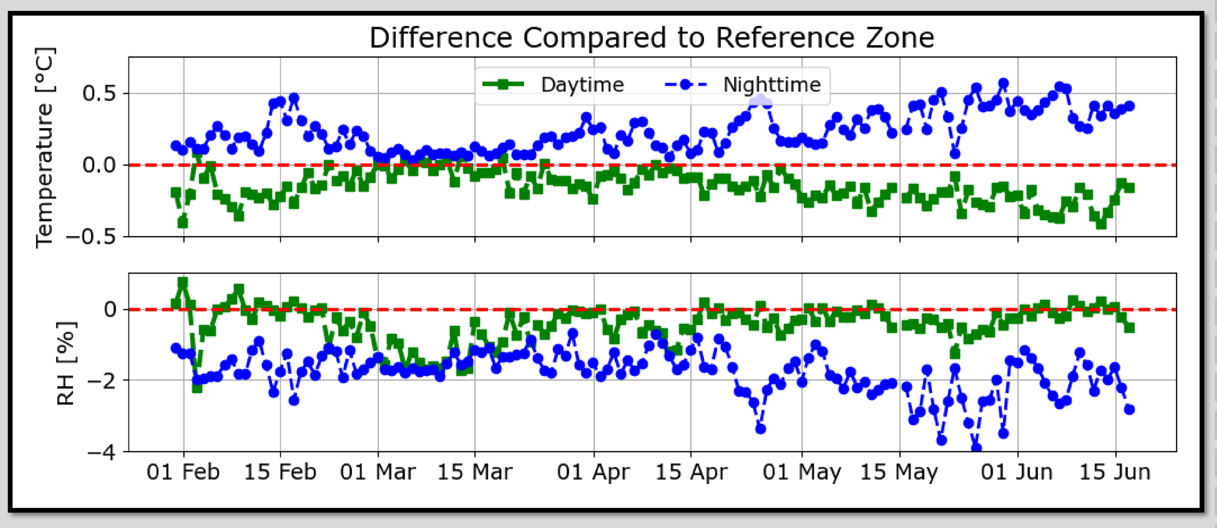


Evolution of PAR radiation across measurement zones on a clear-sky day.



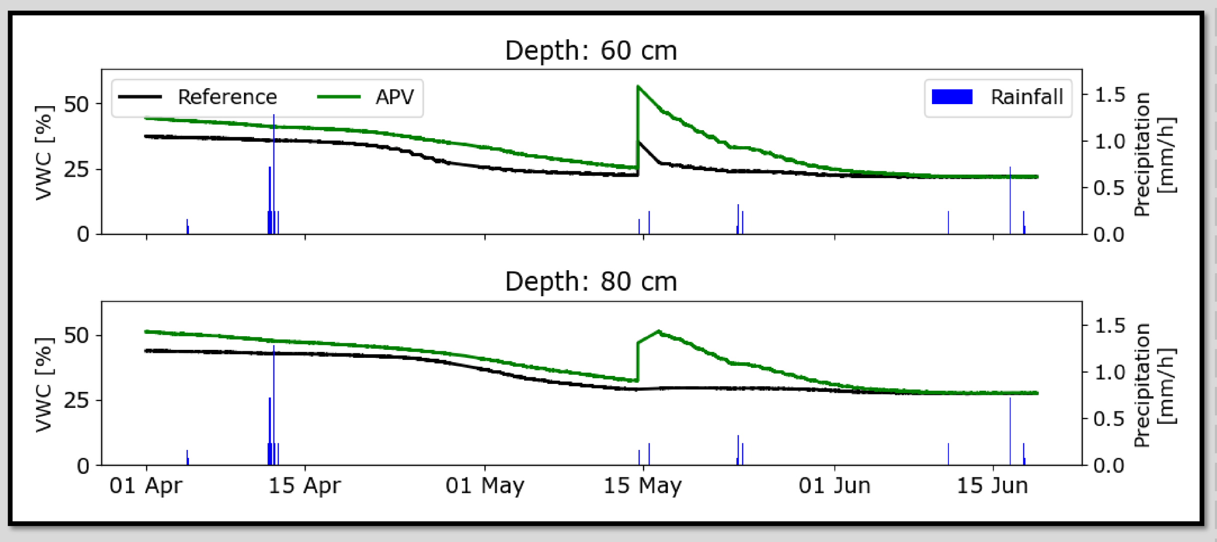
Microclimate & Soil

- Lower temperature during daytime in the APV zone (up to 0.5°C lower during hot days with max. temperatures about 35°C).
- Slightly higher temperatures (+0.6 °C) and lower RH (-4%) during nighttime in the APV zone.
- Correlations with crop yield to be identified after having at least data from 3 different crop seasons.



Soil Moisture

- Comparison of Volumetric Water Content (VWC) at different depths in the reference and APV areas.
- Extended soil moisture retention below the modules in the APV area.
- Higher VWC is maintained for more days after rainfall under the PV modules, thus suggesting that APV systems effectively reduce evapotranspiration.



Summary and Outlook

- **First agrivoltaic installation** in a **vineyard** in Almería, Andalucía, Spain.
- **Farmer benefits**: additional incomes and crop protection from excess radiation and hail.
- **Plant growth: No visible differences** between vines in the **APV zone** and those in the **control area**.
- **Next step:** First crop yield data expected after September harvest; APV impact yet to be fully assessed.

References

1. van Leeuwen et al. (2024), “Climate change impacts and adaptations of wine production”, Nat. Rev. Earth Environ., https://doi.org/10.1038/s43017-024-00521-5
2. https://www.dlr.de/en/sf/latest/news/2025/harvesting-the-sun-protecting-the-vines-a-milestone-for-sustainable-agriculture
3. Cortijo El Cura-Ecobodega. https://cortijoelcura.com/
4. Photone Growth Light Meter, “Light Requirements for Plants”. https://growlightmeter.com/light-requirements-for-plants/
5. Yuan, Y.; et al. (2025) “The Effects of Light Duration and Intensity with Supplemental Light-Emitting Diode Lights on Grape Photosynthesis, Yield, and Fruit Quality”. *Agronomy,* https://doi.org/10.3390/agronomy15030518

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