Modelling Spatial Light Distribution in an Agrivoltaic System for an Ecological Vineyard

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1. Aim of the study

To evaluate the **spatio-temporal distribution of irradiance** at crop level within an **agrivoltaic (APV) system** located in a **vineyard** in **Almería (southern Spain)[1]**, using a **ray-tracing simulation approach**.

A drone picture of the agrivoltaic (APV) setup in an eco-friendly vineyard, located in a valley surrounded by high mountains and fertile farmland with vineyards, olive trees, and almond trees. The system was installed in January 2025 on land owned by Cortijo El Cura – Ecobodega[2].

2. Description of the system

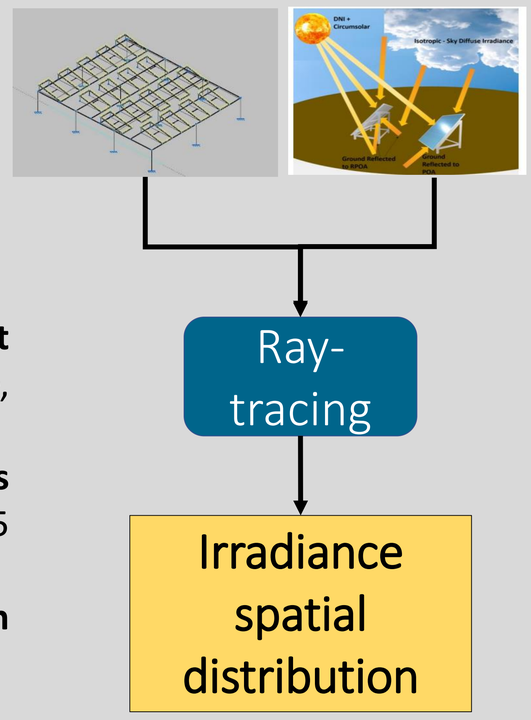
The system comprises **18 PV modules** mounted on a **fixed, southeast-facing structure** at a height of **3.3 m**. The modules are arranged in a **checkerboard pattern** in 4 rows, with **two vine rows planted between each pair of PV rows**. The installation covering a total area of **120 m²**, with a **ground coverage ratio (GCR) of 38%**. The figure below shows a 3D visualization of the system generated with Radiance.

Rendered model of the APV system layout created using Radiance.

3. Methodology

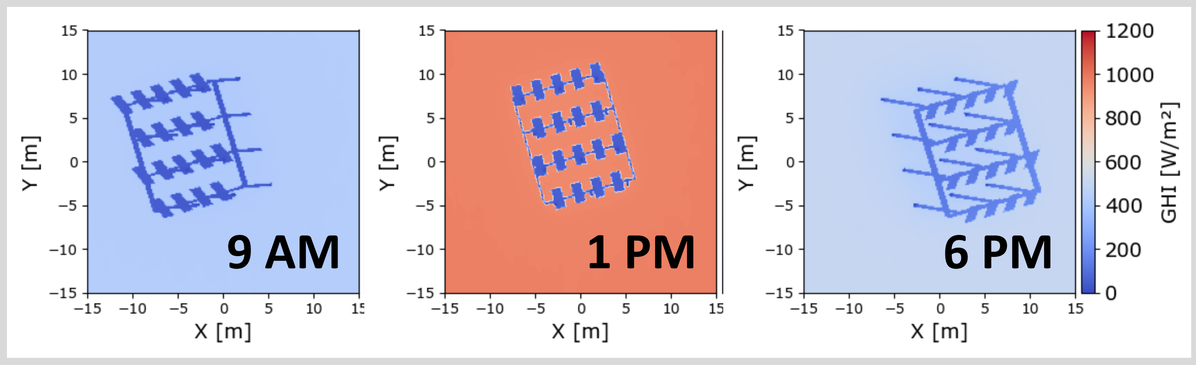
Steps:

a) Irradiance data (**GHI and DHI**) imported from the **CAMS database / TMY.**
b) Specify **soil properties**
c) Implement **scene (Part I)**: number of modules, spatial pattern, albedo and installation settings (tilt, azimuth, height).
d) Implement **scene (Part II)**: supporting structure, obstacles, etc.
e) Create **grid of sensors** (40,000 sensors – 0.15 m resolution).
f) Define the **simulation time period**.

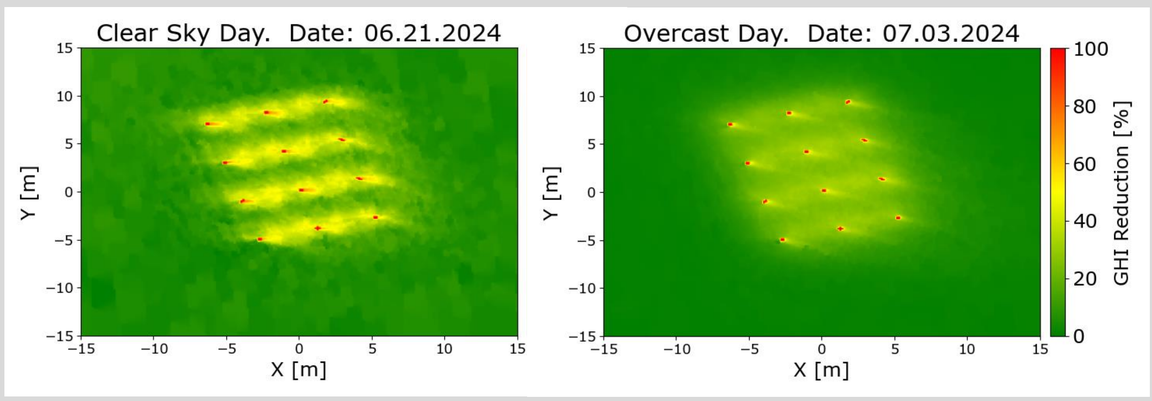


4. Results

- Assessment of shaded area distribution throughout the summer solstice day.



- Evaluation of daily accumulated Global Horizontal Irradiance (GHI) reduction at soil level (height = 5 cm).



- Around **50% to 60% average GHI reduction** below the rows of panels.
- **Less than 20 % GHI reduction** in between rows.
- Greater impact during clear-sky days.

5. Conclusions and Future Works

- **Ray-tracing** simulations allow to estimate radiation distribution at crop level → **Design optimization** of new APV systems.
- **Excessive** Photosynthetically Active Radiation (**PAR > 1200 µmol $m^{-2} \cdot s^{-1}$**) and Daily Light Integral (**DLI > 30 mol m^{-2} d^{-1}**) can negatively **impact grapevine growth[3]**. Ray-Tracing simulations enable **optimization of APV tracking strategies** to enhance light management for crop development.
- **Future efforts** will focus on **validating** simulation results with field measurements and improving **computational efficiency** to support complex and large-scale analyses.
- **Future work** will integrate a transposition model to directly derive PAR values received by plants from modeled GHI.

References

1. https://www.dlr.de/en/sf/latest/news/2025/harvesting-the-sun-protecting-the-vines-a-milestone-for-sustainable-agriculture
2. Cortijo El Cura-Ecobodega. https://cortijoelcura.com/
3. 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
4. Kujawa et al. (2025), "A Ray-Tracing-Based Irradiance Model for Agrivoltaic Greenhouses: Development and Application", https://doi.org/10.3390/agronomy15030665
5. Fernández Solas et al. (2025), "Exploring Agrivoltaics in Viticulture: Opportunities for Southern Spain", AgriVoltaics 2025 conference, Freiburg, Germany.

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