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Light modelling for agrivoltaic applications: Advances from the SYMBIOSYST project

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INTRODUCTION

Optimising agrivoltaic (Agri-PV) systems requires understanding complex light interactions between PV modules, crops, and the environment. Within the SYMBIOSYST project, several advanced modelling tools were developed and benchmarked to improve simulation accuracy and support the design of high-performance Agri-PV systems.

OBJECTIVES

- Simulate light availability and distribution in diverse Agri-PV configurations.
- Benchmark multiple modelling tools against each other and real-case scenarios.
- Evaluate the effects of panel height, spectral filtering, and structural design.
- Support dual land-use designs that optimise both crop productivity and PV yield.

METHODOLOGY

Three modelling tools were used:

- LuSim (LuciSun): GPU-accelerated 3D view-factor-based simulator for complex environments (open field and greenhouse).
- Ray-tracing tool (Imec): Physically based, spectrally resolved ray tracing, with integration of UV-to-PAR optical coatings.
- Radiance-based framework (TU Delft): Extended Radiance modelling with support for porous tree canopies, spectral skies, and semi-transparent PV systems.

The tools were validated using both analytical test cases and realistic demonstrators, such as greenhouse setups and open-field checkerboard scenarios.

RESULTS

- Validation using simple test cases, such as horizontally placed PV modules, showed agreement among the tools for direct and diffuse irradiance components.
- In complex scenarios like checkerboard-patterned ground or greenhouse environments, the tools captured light interactions with diverse materials and geometries.
- Comparisons revealed discrepancies at lower module heights, primarily due to shading and ground reflectance differences, but results converged above 2 metres.
- Simulations of greenhouse glass demonstrated reduced irradiance but improved light uniformity under clear skies, mitigating sharp light transitions.
- Seasonal analyses showed alignment among the models, validating their reliability for long-term agrivoltaic system analysis.

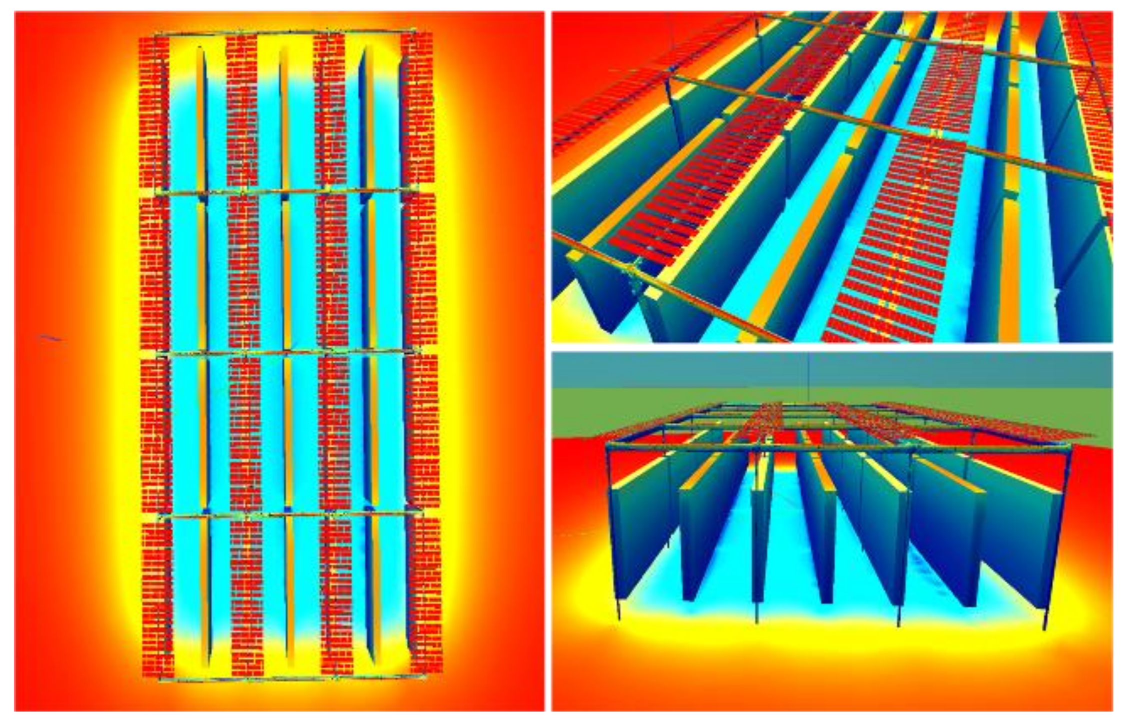
YOU WANT TO KNOW THE DETAILS OF THIS WORK? READ OUR PROJECT DELIVERABLE!

Rajan et al., D2.2: Validation and benchmark of modelling tools for light assessment using ray-tracing and GPU-based method, 2024.
Document available from the website of Symbiosyt in the Results section (https://www.symbiosyst.eu/) or from the QR code.

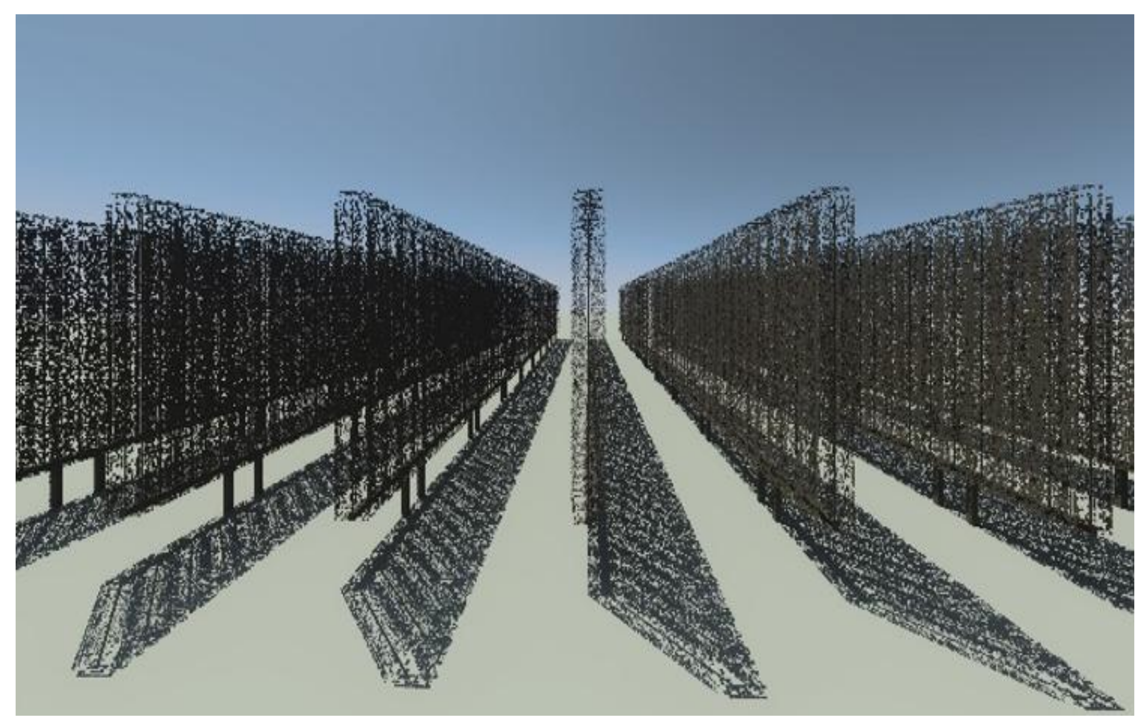
ACKNOWLEDGMENTS

We thank the European Commission for generously funding our efforts to model how sunlight filters through leaves, bounces off soil, and feeds both panels and plants (all things the sun does effortlessly every day) through the research project SYMBIOSYST (https://www.symbiosyst.eu/), part of the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101096352.

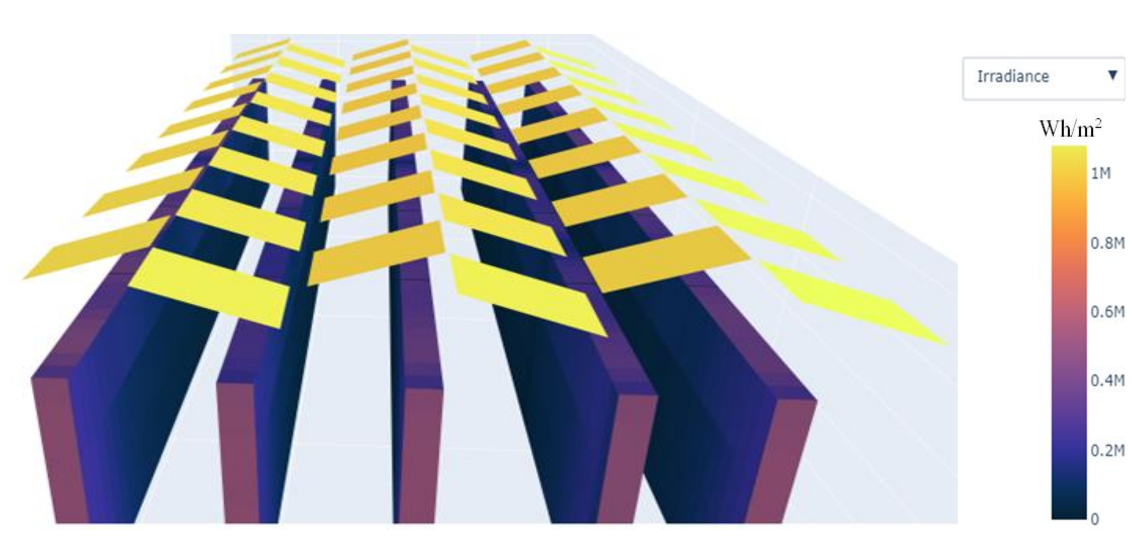
And finally, thanks to Mother Nature for giving us sunlight to enjoy and crops to eat, with or without our simulations.



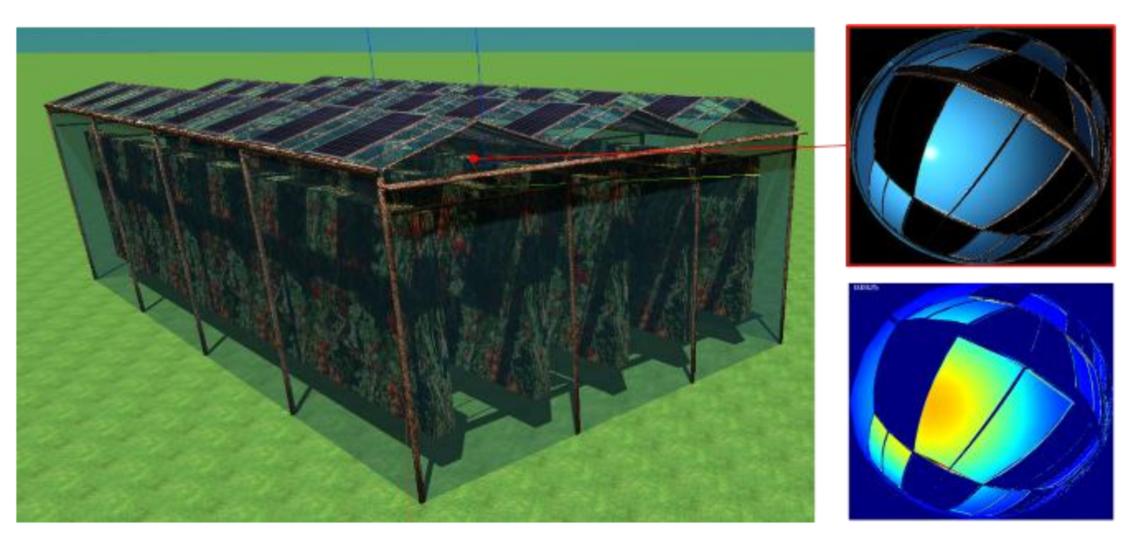
Distribution of diffuse irradiance across the full Agri-PV scene, based on sky visibility calculated from view factors at each point of the triangular mesh. Values are normalised from 0 (low visibility, in blue) to 1 (high visibility, in red).



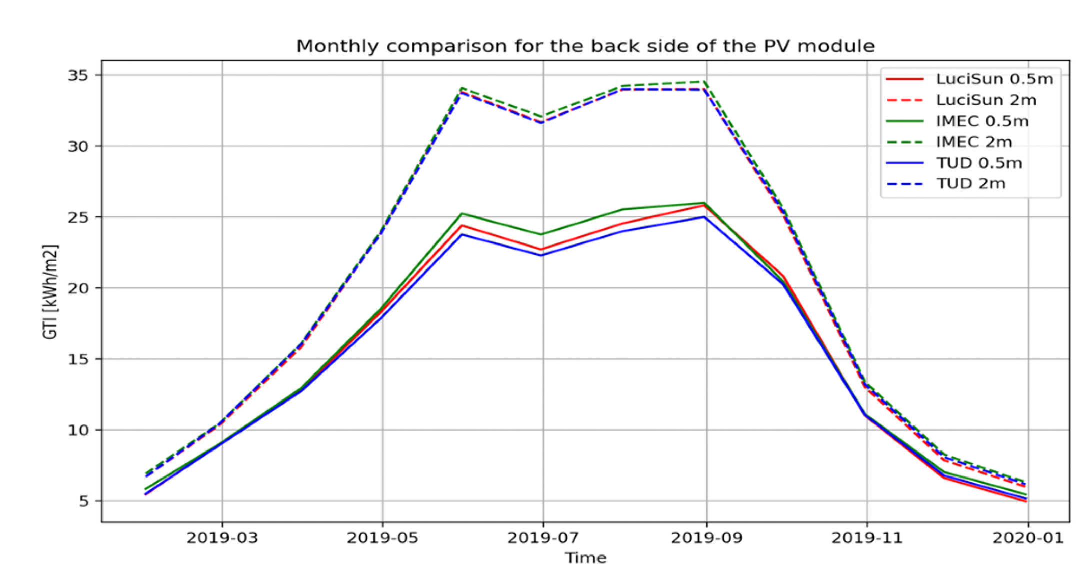
Modelling plant architecture is one of the most complex aspects of Agri-PV simulation, especially for tall, porous tree canopies that strongly influence light distribution. Instead of aiming for exact replication, simplified yet realistic canopy models are used to capture key shading effects.



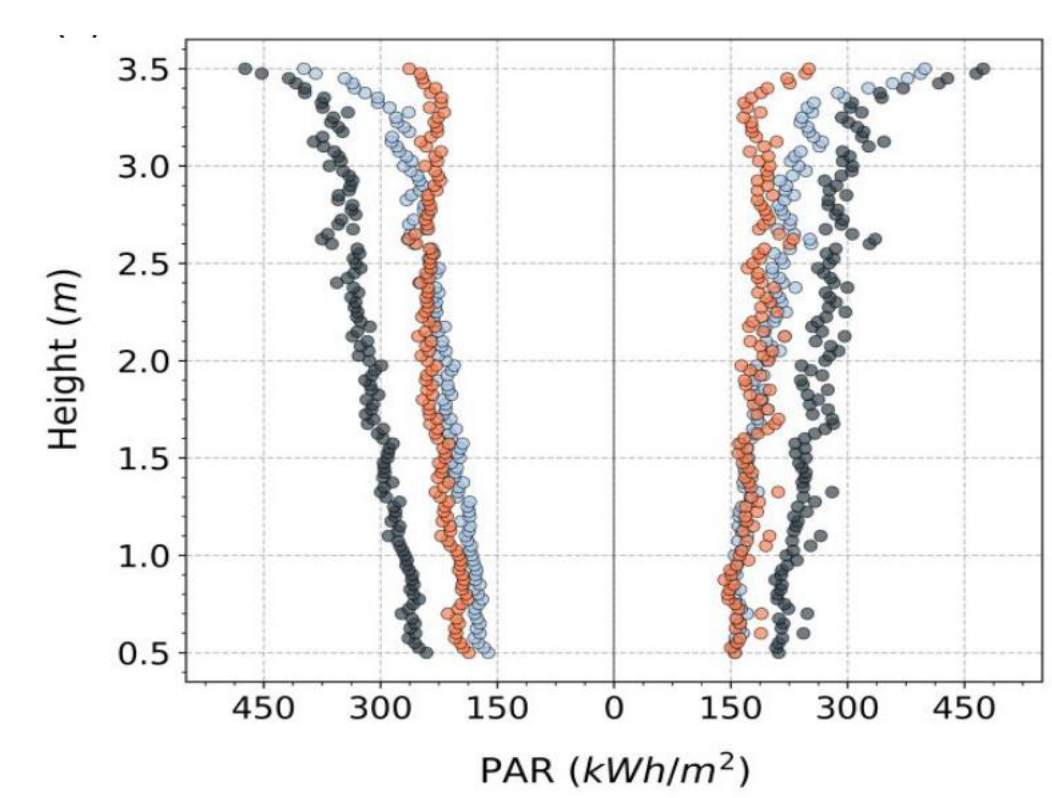
The 3D model of the east-west greenhouse includes detailed geometry of the tomato plants and PV modules, with glass properties set to 85% transmittance and a refractive index of 1.5. Irradiance was evaluated on seven key zones of the plants and modules.



Different models can be used to apply diffusion factors to directional irradiance, each influencing how irradiance contributions are distributed in the scene. The resulting view factor renderings from the observer's perspective vary accordingly.



At 0.5 metres, some models slightly overestimate irradiance during the summer months. These variations are linked to partial shading and the spatial distribution of ground points, which become particularly relevant at lower heights where shading from the PV modules is more pronounced.



Seasonally aggregated profiles of light penetration through the tree canopy show that while overall patterns are similar to a reference orchard without PV, the presence of modules leads to a more uniform vertical distribution of photosynthetically active radiation (PAR) within the canopy.