PASE as a preprocessor to simulate crops growing in heterogenous microclimate conditions with STICS and pySTICS

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Introduction

- The Python Agrivoltaic Simulation Environment (PASE) is a 3D modeling framework originally developed for agrivoltaics (AV) research [1] but it can simulate spatially and temporally heterogeneous microclimates of any complex agricultural systems: AV, agroforestry, orchards, intercropping systems, urban agriculture, greenhouses, etc.
- Microclimate modeling in PASE is for now limited to detailed light simulations and an empirical wind model for vertical structures such as vertical AV or windbreaks (Figure 1).
- As microclimate heterogeneity significantly influences crop development and productivity, future developments aim to incorporate additional microclimate components to enhance environmental realism.
- The STICS radiative transfer formalism is restricted to crop canopy geometry and relies on spatially averaged state variables➔ STICS cannot explicitly address 3D heterogeneity or shading from non-plant structures, limiting its applicability to complex environments.
- To address this, PASE serves as a preprocessor for STICS/pySTICS, producing spatially and temporaly high-resolution and explicit microclimate data.

Preprocessing of light microclimate

- Parametrization of the site configuration and numerical aspects of the simulation occurs via documented (parameter's role, unit, type and range of accepted values) YAML files.
- Weather data needed are global horizontal irradiance (GHI, W/m^2), air temperature (°C) and wind speed (m/s) with a sampling period between 1s and 1h and precipitation (mm) and vapor pressure (hPa) at any timestep between 10 min and 1 d. The three first can be automatically downloaded from PVGIS based on the site's location while the last two must be provided in data files.
- PASE initiates ray casting light computations in the scene by computing sun positions and irradiance components, preparing the 3D scene (PV modules, trees, buildings, ...), placing interest points in the scene and discretizing the sky dome (Reinhart discretization model [2]).
- Ray casting occurs for each interest point of the scene at each timestep and runs in parallel to reduce computing time.

- The direct light part provides a Boolean mask: each interest point is either in the shade or under direct irradiation from the Sun. Direct horizontal irradiance is then applied on the mask.
- The diffuse light part provides a sky view factor computed as the fraction of sky area not obstructed by obstacles over total sky area. It is then weighted with the cosine of the zenith angle and the anisotropic sky radiance distribution, which depends on Sun position and sky type [3, 4] and multiplied by the diffuse horizontal irradiance.
- Finally, the direct and diffuse components are summed for each timestep and integrated on the day.

Results and discussion

- Figure 2 illustrates the resulting spatialized daily irradiation at the crop level. This and other weather data are then fed into the crop modeling step of the workflow, as parametrized by the user (SIMPLE, Gras-Sim, JavaSTICS or pySTICS).
- Crop development is therefore also computed for each interest point of the scene, accounting for the local light microclimate.
- In the current coupling, PASE provides a 3D description of the light environment, while STICS/pySTICS remains responsible for the crop thermal balance based on this radiative input. In the longer term, however, thermal microclimate processes will also be explicitly simulated within PASE.

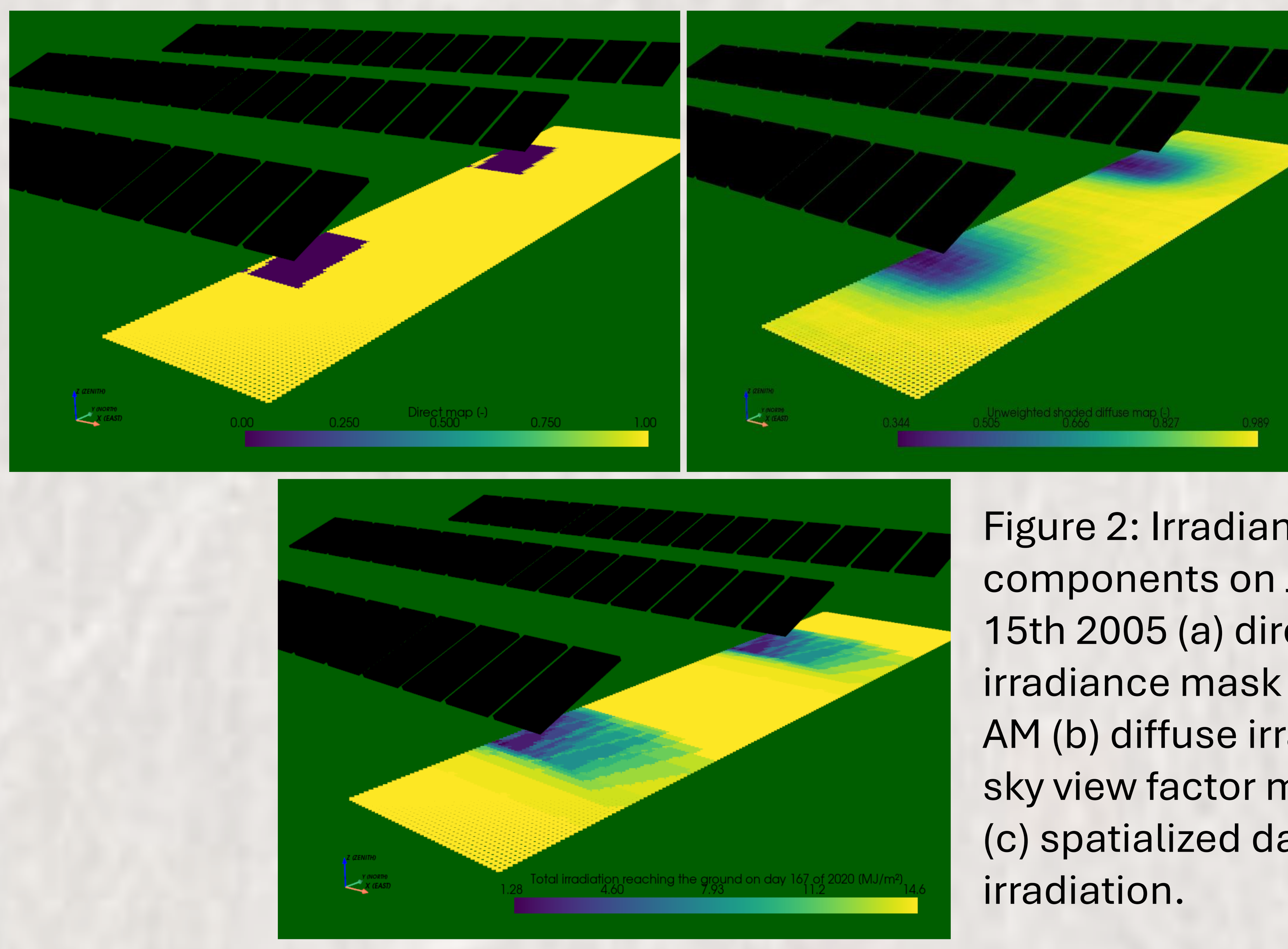

Figure 2: Irradiance components on June 15th 2005 (a) direct irradiance mask at 10:00 AM (b) diffuse irradiance sky view factor map and (c) spatialized daily irradiation.

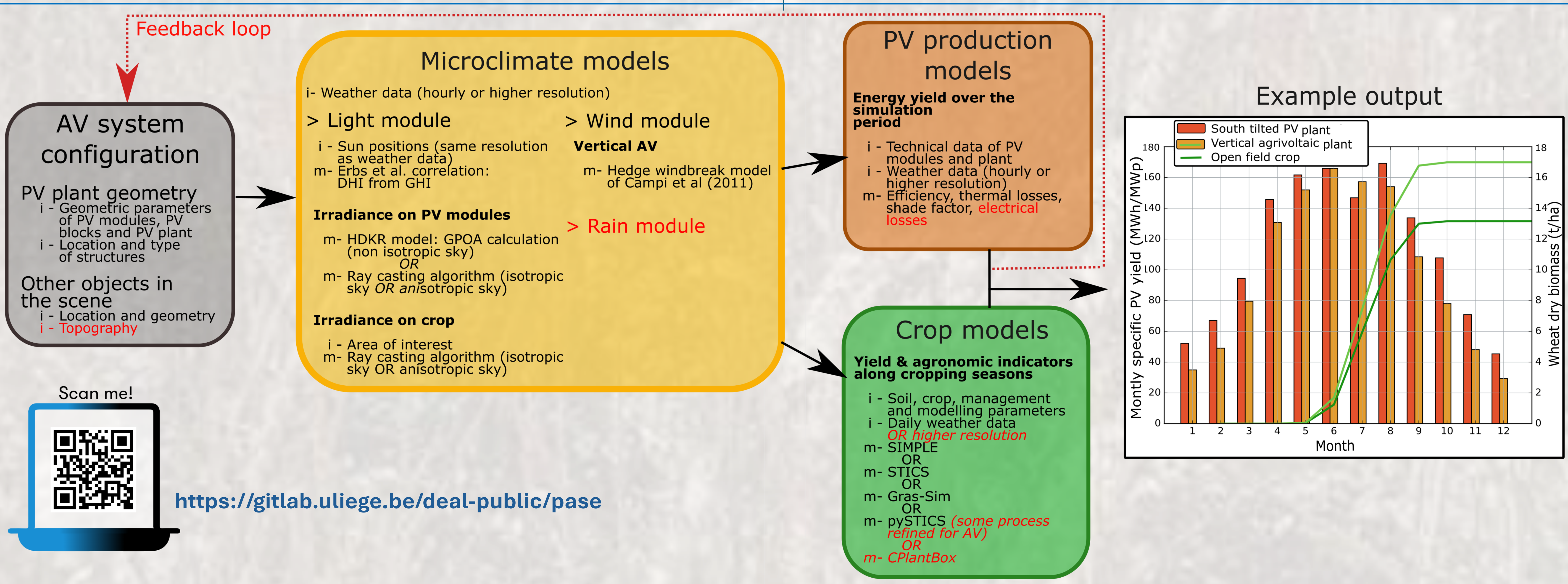

Figure 1: PASE 1.3.0 organigram: main modules and their interactions, the inputs (i -), the models (m-) available (in black) and the future developments (in red).

References

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