

PASE: a Python Agrivoltaic Simulation Environment

Bruhwyler Roxane¹, Nicolas De Cock¹, Lemaire Louis¹, Bouvry Arnaud¹, Brunet Pascal²,
Leloux Jonathan³, Frédéric Lebeau¹

¹DEAL, BioDynE, Université de Liège: 2 passage des déportés, 5030 Gembloux, Belgique, +3281622165
f.lebeau@ulg.ac.be

²Naldeo Technologies Industries: 19 rue Hélène Bouchet, 40220 –Tarnos–France

³LuciSun: 29 rue Saint-Jean, 1495 Villers-la-Ville

1. Introduction

Agrivoltaics (APV) modelling is a recent investigation field driven by the rapid pace of development of research to optimize the synergy between agricultural and energetic production in dual land use projects. According to the technical discipline of the principal investigator, developments are usually based on available softwares and standards after which functionalities are extended to include third party expertise and knowledge. This approach reduces the development duration and errors but quickly faces limitations when more collaborative work is expected between multiple stakeholders. Indeed, limited scalability slows down the process of integrating new knowledge resulting from the scientific and industrial communities feedback. Last but not least, software property issues may appear during the valorization phase.

Open-source software based on permissive licenses are powerful tools to stimulate collaboration between parties while guaranteeing freedom to use and commercialize developments. Many open-source software tools are currently available in a Python environment, which is becoming a lingua franca in engineering research. Furthermore, Python offers many tools to develop applications such as dashboards, GIS-interfaces, digital twins, data analysis, etc.

This paper introduces the tool Python Agrivoltaic Simulation Environment (PASE) developed to facilitate the collaborative work between academic and industrial partners. It aims to analyze and design efficient systems using a modular framework approach that is open to further developments and collaboration among various stakeholders.

2. Framework Architecture

Figure 1 presents the global architecture of PASE in its current version (available at: [1]). Each block represents a module with its different components. Inputs (i-) and models (m-) available for the simulations are listed for each component. PASE has been developed with user-friendliness as a core design principle. Therefore, a user can simply run a simulation by filling some YAML input files and launching the main file of the framework. Input files allow the user to define the parameters of the APV plant (geometry, PV technology, crop cultivated, etc.) and to make a choice between the different models available. The modularity of the framework is its main advantage, enabling to switch from one model to another as needed. For example, different crop models are already implemented and can be used depending on the complexity required and the crop being studied. Simulations will provide detailed outputs on PV production and the state of the crop in CSV files as well as graphical results. Some examples of results are presented in Figure 2 to illustrate PASE's current capabilities. Because of the inter-annual variability of crop yields, the production of agrivoltaic systems should be assessed over several years [2]. With this idea in mind, PASE has been developed to enable fast computations by avoiding repetitive calculations and allowing the user to choose between different levels of precision and resolution depending on its needs.

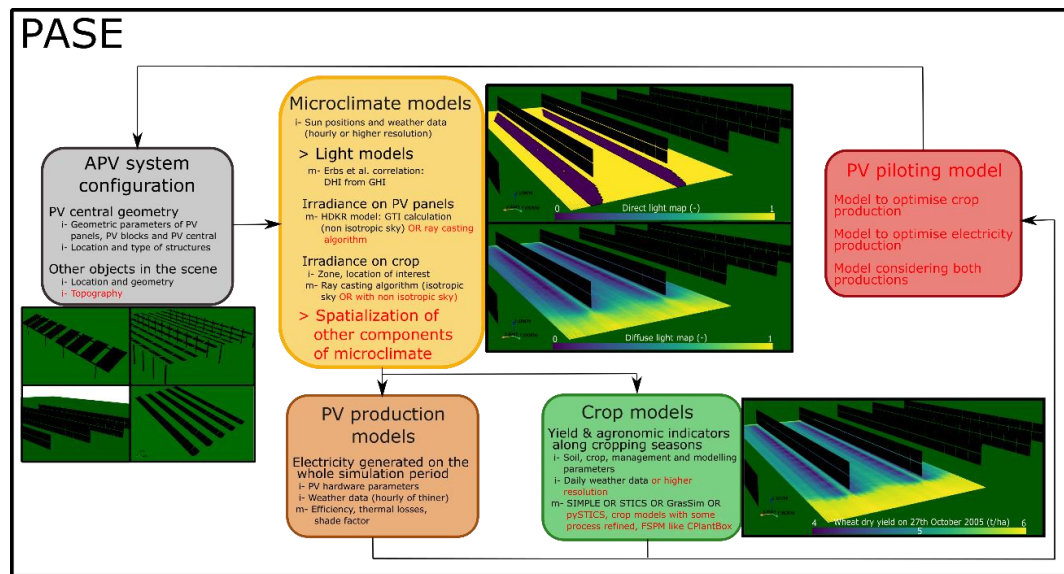


Figure 1. Organigram of the current version of PASE with its main modules, links between them, their inputs (i-) and models integrated (m-). Future developments planned are presented in red.

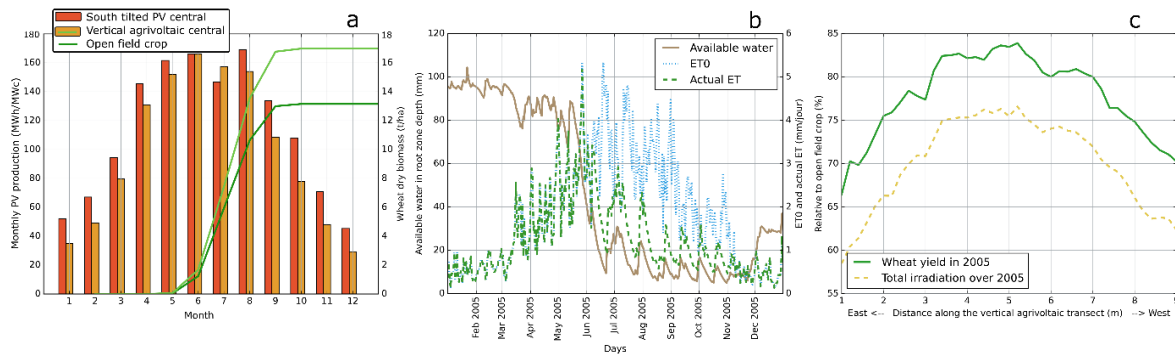


Figure 2. (a) Comparison of the productions of a vertical APV system and the decoupled productions with a south-tilted PV system and a crop in open field. (b) Daily available water and ET fluxes averaged over the transect of a vertical APV system. (c) Total irradiation and wheat dry yield of year 2005 along the transect of a vertical APV system relative to open field crop.

3. Conclusion and perspectives

PASE was developed to ensure easy development of agrivoltaic simulation according to user needs. The modular architecture opens a wide range of possibilities. Most importantly, it fosters collaborative work between experts in various domains and user profiles, adhering to an open-source philosophy. Future improvements are planned. A Python version of STICS called pySTICS is currently being developed to become native in the environment and ease collaborative research between industry and academics in France. Other crop models as WOFOST are needed to broaden the user community. Other priorities include transposition models, sky models, forward ray-tracing capabilities, dynamic photosynthesis, tracker control law models, bifacial_radiance compatibility, etc.

4. References

1. Access to PASE's code: <https://hdl.handle.net/2268/310262>
2. C. Dupraz, "Assessment of the ground coverage ratio of agrivoltaic systems as a proxy for potential crop productivity," *Agroforest. Syst.* (2023), doi: <https://doi.org/10.1007/s10457-023-00906-3>