Testing the capacity of an oil palm FSPM to simulate changes in water and carbon dioxide fluxes under a range of climatic conditions

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Functional-structural plant models (FSPM) aim at reproducing the complexity of the ecophysiological and developmental responses of plants to their environment. Such models can be particularly useful to understand and explore plant behaviour in a changing climate, but depend on intensive collection of structural and ecophysiological data. Since errors can rise from different sources such as model implementation, calibration, and coupling, model evaluation can be a major difficulty. Furthermore, some sub-models simulate processes at fine scale (*e.g.* leaf scale) but the output of interest is an integration at a larger scale (*i.e.* plant or plot scale), which can also add error that is difficult to assess when evaluation is only made at the finer scale. Lastly, very few databases are available for the assessment of FSPM because they require expensive and time-consuming measurements, including plant geometry and sometimes topology, ecophysiological data such as response curves (*e.g.* A-C_i), and whole-plant measurements to control for the error coming from the upscaling. Consequently, the assessment of an FSPM as a whole is usually omitted because of the lack of such data.

In this work, we first propose a new dataset dedicated to FSPM evaluation at leaf to plant scale. Oil palm plants were placed in a microcosm (Montpellier European Ecotron) where H_2O fluxes, CO_2 fluxes and leaf temperature were measured continuously while air temperature, vapor pressure deficit, photosynthetically active radiation and air CO_2 concentration were finely controlled (Fig 1A). Climate conditions were modified sequentially and independently to obtain eight daily climate scenarios replicated on four plants, allowing the investigation of the impact of climate variables on plant assimilation and transpiration. The dataset also include data for the parameterization of the models, including fine reconstructions of the 3D plant structure from terrestrial LiDAR point clouds (Fig 1B) and measurements of photosynthesis and stomatal conductance using leaf-scale response curves from a gas analyzer, including A/Ci, A/PPFD and Gs/VPD response curves. The three-dimensional reconstruction of the plants and the microcosm were then used to build a digital twin of the experiment.

Secondly, we propose an example evaluation of an FSPM (Treillou et al., in prep., Perez et al. 2022) using this database, and explored how plant transpiration and carbon assimilation were modulated under the contrasted climate scenarios (Fig 1C). Then we tested the accuracy of the biophysical models to simulate these physiological changes, and discussed the discrepancies between observations and simulations. The database presented is unique regarding the complementarity and completeness of the observations made, and would allow testing hypotheses on the spatial integration of physiological processes, and the degree of accuracy required in the representation of plants to properly take into account the relationship between structure and functions in FSPM.

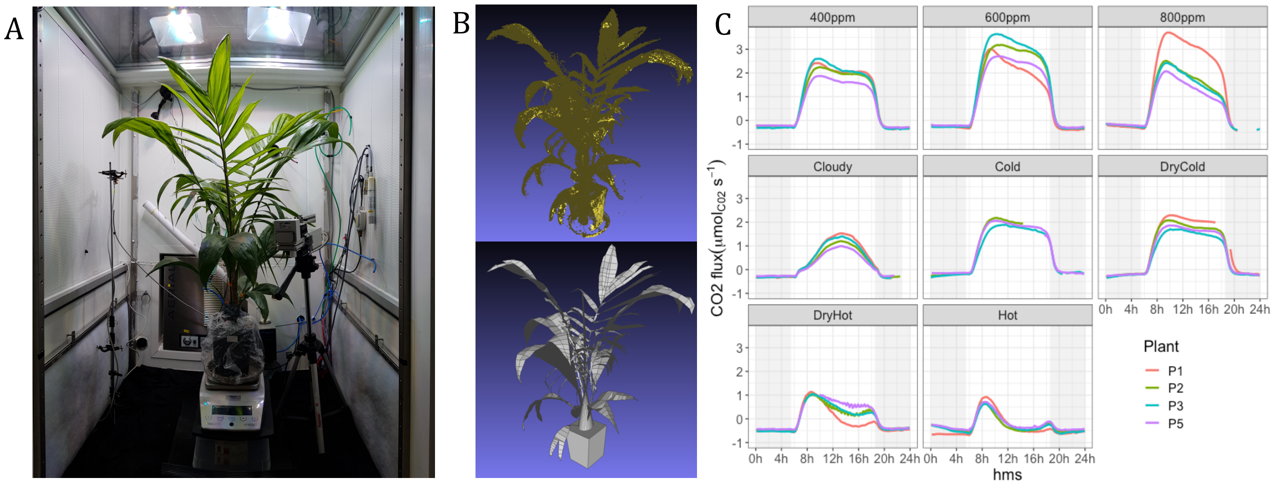

Figure 1: A) Experimental device with monitoring of climate conditions and measurements of physiological processes. B) Reconstruction of the 3D plant structure (bottom) from terrestrial LiDAR point cloud (top). C) Measurements of CO_2 fluxes for the four studied plants (colours) under the eight contrasted climate scenarios.

References

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