

Leveraging Species Composition for Yield Improvement in Agrivoltaic Projects on Extensively managed Grasslands

Lemaire Louis¹, Bindelle Jérôme², Lebeau Frédéric¹

¹ DEAL, BioDynE, Université de Liège, Passage des Déportés 2, 5030 Gembloux, Belgium,

² Animal Sciences, Université de Liège, Passage des Déportés 2, 5030 Gembloux, Belgium,

1. Introduction

Simulating outcome of agrivoltaics systems is key for the development of this sector. In the context of grazing herbivores in agrivoltaics settings, differences in grassland species will influence the productivity of the system through its impact on growth dynamics throughout the season, macronutrient contents and digestibility, animal attractivity and sensitivity to fertility, water availability and shading. Both plant biomass quality and quantity are important, hence the need to consider the impact of botanical composition when performing agrivoltaic growth simulations. Gras-Sim [1] simulates of the growth dynamics of multispecies grasslands by grouping several grass species in four Plant Functional Types (PFT), each characterized by a specific phenology, a strategy towards the capture of resources and nutrient content parameters. The model simulates the growth, the aging and the senescence of vegetative and reproductive plant compartments, as well as soil water and nitrogen dynamics while incorporating management scenarios such as fertilization and grazing or mowing. Its outputs include biomass yield, forage quality (digestibility) and nitrogen content available for export (via grazing or cutting). Four main grass PFTs are used: PFT A, species growing on fertile soils, with a fast recycling of organs translating into an early development at the beginning of the growing season with high growth rates but not allowing the accumulation of high levels of standing biomass; PFT B, displaying a slower recycling of organs and thus slightly later species allowing for higher levels of biomass accumulation; PFT C, slower growing species on poorer soils with lower nutritional value; PFT D, low-quality late growing species on infertile soils, typical of extensively managed grasslands. Using Gras-Sim, this study aims to quantify the yield differences between PFT for a specific case-study.

2. Materials and methods

Gras-Sim model is used in the Python Agrivoltaic Simulation Environnement (PASE 1.0) [2] framework for one-year agrivoltaic grassland growth simulations. In its current implementation, Gras-Sim does not account for temporal changes in PFT proportions. The study is conducted for the location of Gembloux, Belgium, using 2015 PVGIS weather data. Grassland management practices are standardized, with mowing at a mean sward height of 35 cm and fertilization (60 kgN_{mineral}/ha) three days post-mowing. A control scenario without PV installation is compared to a vertical North-South PV installation with 20% coverage ratio. To assess individual PFT impact on productivity, single-PFT grasslands are simulated. Initial biomass is set at 1000 kg/ha.

3. Results and discussion

The main variable of interest is the total digestible biomass production. On-field biomass dynamics and biomass accumulation (including exports) are also shown in figure 1.

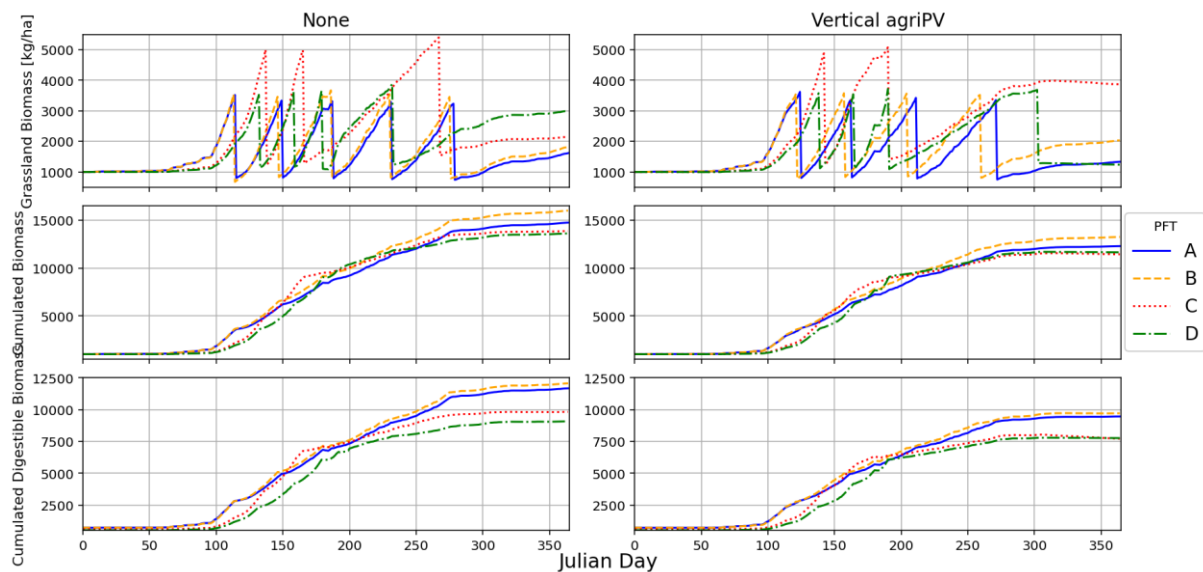


Figure 1. One-year biomass dynamics of single-PFT grasslands for no PV installation and vertical panels.

In this specific scenario (one year, one location), shading reduces total digestible biomass production by 19–25%, depending on the PFT. However, agrivoltaic grasslands with high-quality PFTs (e.g., PFT A and B) can match or exceed the productivity of control grasslands with lower-quality PFTs. Specifically, an agrivoltaic grassland dominated by PFT B (best agrivoltaic scenario) achieve 7% higher yield compared to a control grassland dominated by PFT D (least favorable control scenario). These results emphasize the value of optimizing PFT composition and using simulation tools for effective management. Agrivoltaic developers can utilize such tools with initial PFT diagnostics to enhance system performance. Future work will improve the modelling framework. First, additional PFTs, including legumes and weeds, will be implemented. Second, the long-term dynamics of PFT proportions will be modelled using Gras-Sim over multiple decades. Third, spatially explicit grazing animal behaviour will be modelled on grasslands with heterogeneously distributed PFTs, allowing for a more refined representation of PFT proportion evolution and enabling the study of grazing refusal area formation. Finally, simulation outcomes will be compared with high-resolution spatialized data collected using an unmanned autonomous ground vehicle equipped with RGB-D sensors, developed as part of the ongoing RobHerb [3] project.

4. References

1. E. U. Kokah, et al. "Modeling the daily dynamics of grass growth of several species according to their functional type, based on soil water and nitrogen dynamics: Gras-Sim model definition, parametrization and evaluation," *Journal of Agriculture and Food Research*, vol.14, no.100875, Dec. 2023, doi: <https://doi.org/10.1016/j.jafr.2023.100875>.
2. R. Bruhwylter, et al. "Modelling light-sharing in agrivoltaics: the open-source Python Agrivoltaic Simulation Environment (PASE 1.0)," *Agroforest. Syst.*, vol.98, pp.2747-2764, Oct. 2024, doi: <https://doi.org/10.1007/s10457-024-01090-8>.
3. M. Houry. "Mise au point d'un système d'acquisition et de traitement de l'information pour la gestion des prairies pâturées." ROBHERB. <https://robherb.be/> (Jan 10, 2025).