MAELIA: an integrated modelling and assessment platform to support a sustainable bioeconomy

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Abstract

Achieving carbon neutrality by 2050 and broader sustainability goals requires transformative approaches that reconcile food and non-food biomass production with the conservation and regeneration of natural resources. Local to regional bioeconomy projects allow combining diverse strategies, including agroecological systems, optimized biomass-chains and resource use, collective action, and virtuous circles of interactions (e.g. circular economies, stronger rural-urban links).
The design of a sustainable territorial bioeconomy system requires a multi-criteria, and multi-level *ex-ante* assessment approach to identify the trade-offs to be manage and the possible synergies of transition scenarios (Wohlfahrt et al., 2019). Integrated Assessment and Modelling (IAM) approaches offer a powerful framework designed to address complex sustainability issues and support both assessment and decision-making purposes (Hamilton et al. 2015). By enabling the integration of diverse knowledge systems (general multidisciplinary and empirical knowledge), IAM provide stakeholders with actionable information on the environmental, social, and economic impacts of potential future scenarios of structure and dynamics of social-ecological systems, such as bioeconomy systems.

MAELIA is a multi-agent platform for IAM of agricultural and bioeconomy systems at local to regional level. MAELIA simulates, on a daily time step, the interactions between biomass production system, biomass value-chains (processing chains and cascade), recycling activities. Regarding agricultural systems it simulates interactions between agricultural practices, biogeochemical cycles (water, N and C), crop growth and farm's socioeconomic performances, taking into account climate and agricultural price variability. Crop management strategies involving vegetal cover management (annual and perennial crops and cover crop), mineral and organic fertilization (e.g., organic inputs), irrigation and crop residue management are explicitly simulated on a field scale. Developments carried out have enabled MAELIA to incorporate an explicit representation of the structure and dynamics of organic waste chains, as well as a dynamic version of the SYS-METHA model of biogas plants that simulates the production of energy, digestate (quantity and quality) and associated N2O and NH3 emissions.

MAELIA enables assessment of a wide range of performances over a multi-year period, from plot level to territorial level, via socioeconomic indicators (gross margin, working time, production, etc.), agro-environmental indicators (yield, nitrate leaching, ammonia emissions, TFI, GHG emissions, etc.) and ecosystem services (nitrogen supply, water quality regulation, C storage, soil quality, etc.). These indicators can be analyzed dynamically to assess the

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resilience/vulnerability of performances to climate (past or future) and/or price variabilities.

MAELIA is modular and, by activating various models and modeling options, is used to define a modeling solution tailored to the issues to be addressed in a given territory. MAELIA has been applied in a variety of French territories to address issues relating to water management, crop-livestock systems, organic wastes management and the development of agro-ecological systems.
The SLAM-B project (FairCarboN PEPR, C6.5m, 2023-2028) aims to expand MAELIA's functionalities to make it an operational and generic IAM tool for supporting stakeholders in designing a circular green bioeconomy. MAELIA will be applied in 7 contrasted living-labs situated in France (metropolitan and overseas departments) and Senegal and will integrate models of biorefineries, livestock farming, forest growth and management, urban metabolism and socio-economic indicators of biomass value-chains. This project will also structure the MAELIA platform for application on a French and European scale, providing decision-makers with a large-scale planning tool dedicated to agriculture and the bioeconomy. SLAM-B therefore aims to significantly increase MAELIA's genericity with regard to territorial bioeconomy issues, positioning this platform as a key tool in this field, in France and internationally. To meet the growing demand for use of the platform, which was no longer a concern of the academic sphere, the start-up MAELAB (https://www.maelab.fr/) was created in July 2021. MAELAB is responsible for deploying MAELIA in the economic sphere.

Keywords: Integrated Assessment and Modelling (IAM), Territorial scale, Agent, based modelling, MAELIA plateform, Circular bioeconomy, Social, ecological system