

PhD Position

Integrating Feedback Dynamics into Life Cycle Assessment

CONTEXT

The BIOCaP-LCA¹ project aims to advance consequential Life Cycle Assessment (LCA) methods to evaluate the environmental impacts of bioeconomy deployment scenarios at the scale of France. While LCA is widely used to assess products or compare technologies, it has limitations when applied to large-scale, long-term transitions that involve complex socio-economic and biophysical dynamics. The project focuses on some key challenges specific to the bioeconomy, including accounting for land use and land-use change (LULUC), impacts on climate and biodiversity, and feedback loops between natural systems (the ecosphere) and human systems (the technosphere), which are not well captured in traditional LCA. To address these issues, BIOCaP-LCA proposes an innovative approach that combines LCA with biophysical and socio-economic models in a dynamic and forward-looking framework.

The project is funding three PhD theses that will lead to methodological advances in these research areas, including the PhD thesis described in this offer.

PHD OBJECTIVES

Historically, LCA has relied on a strict division between the technosphere (human production systems) and the ecosphere (natural systems)². Within this framework, LCA primarily quantifies the impacts of the former on the latter. However, this one-directional perspective constrains its ability to represent feedback mechanisms whereby environmental changes influence human systems in return.

Such limitations have been increasingly highlighted in the literature³, particularly within Consequential LCA (CLCA), where the emphasis on causality calls for modelling approaches that transcend this rigid boundary. In reality, environmental and socio-economic systems are deeply interdependent. For instance, emissions of fine particulate matter can deteriorate human health, increasing demand for healthcare services, which in turn generates additional emissions—creating reinforcing feedback loops. Despite their importance, such dynamics remain largely absent from current LCA practice.

This PhD work aims at tackling this absence by exploring the coupling of LCA with System Dynamics, a modelling approach which is particularly suited for dynamic feedback modelling⁴. Rather than attempting a simple integration of the two frameworks, the project will leverage the causal and temporal structure of SD to explicitly identify, formalize, and analyze feedback loops linking emissions, environmental impacts, and product demand.

The PhD thesis consists in an interdisciplinary and explorative modelling work whose main challenges will be:

- Navigating the modelling interdisciplinarity
- Select, build and study relevant environmental feedback loops
- Extract relevant indicators from SD feedback loops to integrate into LCA
- Assess the substantial uncertainty inherent to the SD framework and to prospective modelling

¹ An ANR-funded PEPR project bringing together INRAE, CEA, IFPEN and CIRAD to advance LCA modelling for the bioeconomy:

<https://www.pepr-bioproductions.fr/eng/funded-projects/axis-4-cross-cutting-methodologies-and-tools/biocap-lca>

² <https://doi.org/10.1007/978-94-015-9900-9>

³ <https://doi.org/10.1007/s11367-017-1398-4>

⁴ <https://doi.org/10.2307/3010125>

The empirical focus will be on the bioeconomy, where feedback mechanisms are particularly pronounced. Agricultural and biomass-based systems both depend on and alter ecological processes, including biodiversity dynamics, water cycles, air pollution, and human health. These tightly coupled interactions make the bioeconomy a critical domain for advancing feedback-aware assessment methods.

At a time when human activities increasingly destabilise the environmental systems that underpin societal well-being, this PhD thesis offers an opportunity to push the methodological frontier of sustainability assessment. By enabling LCA to capture environmental feedbacks, the research aims to support more robust, forward-looking, and scientifically grounded decision-making, and to better anticipate risks of systemic environmental degradation.

WHO WE ARE LOOKING FOR

We are seeking a curious and proactive student with a strong inclination toward systems thinking, and holding a Master's degree (M2).

Experience in quantitative environmental modelling is required, whether in System Dynamics or LCA. While expertise in both is not expected, a clear interest in bridging these two approaches is important. Solid mathematical skills are valued, particularly familiarity with differential equations, which underpin System Dynamics.

Candidates must have excellent English writing and communication skills.

WORK ENVIRONMENT

The PhD student will be hosted within the ITAP research unit located on La Gaillarde campus (about a 10-minute bike ride from the city centre and the train station). Within ITAP, you will join the ELSA research team composed of researchers and engineers specialized in advanced LCA modelling.

The student will be co-supervised by Dr. Pierre Jouannais (INRAE) and Dr. Eléonore Loiseau (INRAE), both of whom have extensive expertise in LCA, particularly in CLCA and in coupling LCA with other modelling approaches.

↘ Practical information

- Location: Montpellier
- Contract: PhD Position
- Duration: 36 months
- Beginning: Autumn 2026
- Salary: 2,300€ gross monthly

↘ How to apply

Send a CV and motivation letter (references are also appreciated) to:

pierre.jouannais@inrae.fr

and

eleonore.loiseau@inrae.fr

Application deadline: **19 June 2026**