M2 Research Internship: Integrating Spatial Dynamics of Pests and Conservation Biocontrol for Sustainable Agriculture

Laboratory name : CFM Chair of Econophysics & Complex Systems, LadHyX
CNRS identification code : UMR CNRS 7646
Internship location : Ecole polytechnique (Palaiseau), and CFM (Paris)
Thesis possibility after internship : YES

Supervision : Elia Moretti and Michael Benzaquen

Email : michael.benzaquen@polytechnique.edu

Abstract

Biodiversity loss driven by agricultural intensification is a pressing global issue with significant implications for ecosystem stability and human well-being. Here, we aim to extend our recent work on bioeconomic modeling to mitigate farmland biodiversity loss (see [1]) by incorporating the spatial dynamics of pests and conservation biocontrol (see [2]). We believe this integration is crucial for a more granular understanding and for providing more comprehensive policy recommendations.

Motivation and background

In recent decades, Europe has witnessed a dramatic reduction in biodiversity, with significant declines in both the overall biomass and the number of different species. Likewise, the number of species at risk of extinction has risen. The decline is particularly severe in farmlands, where bird populations have shrunk, the number of pollinators has dwindled, and invasive species are increasingly infiltrating agro-ecosystems. Modern agriculture is widely recognized as the primary driver of this trend.

Agriculture covers nearly a third of Europe's land area (and about half of France), making it the predominant land use. Rising food demand has driven agricultural intensification, which relies heavily on chemical inputs like fertilizers and pesticides. These chemicals disrupt ecological balances, harming biodiversity and leading to population declines. Additionally, international competition has prompted significant land consolidation, merging smaller farms into larger, uniform fields to boost efficiency. While this transformation benefits large-scale farming, it adversely affects biodiversity by removing diverse habitats such as hedgerows, ditches, and grass strips with wild vegetation, which are crucial for supporting various species.

Biodiversity plays a crucial role in the functioning of our ecosystem, underpinning essential services for societal well-being such as water provision and air purification. Extensive research has thus been conducted by ecologists and economists to try to halt the ongoing environmental degradation. This being said, effectively addressing agro-environmental sustainability requires a holistic approach that integrates both ecological and economic perspectives. In other words, interdisciplinary research (in terms of both concepts and methods) is key if we are to comprehensively grasp the complex interplay between farmland ecosystems and their economic counterparts.

To that end, we recently introduced an integrated bio-economic agent-based model, informed by historical data from the French agricultural sector, to project future biodiversity trends and evaluate policy interventions [1]. Our approach stands out due to its use of micro-foundations to analyze past and future trends in biodiversity loss, pesticide use, and land consolidation. We evaluated various policy interventions and found that the most effective strategy for mitigating biodiversity degradation combines pesticide reduction with targeted subsidies for small farmers. A limitation of the model, left for future work, is the lack of a spatial dimension.

Subject

The goal of this internship is to integrate the spatial dynamics of pests and conservation biocontrol. We will begin by attempting to combine our previous framework [1] with an abstract, spatially explicit reaction-diffusion model of pests and their natural enemies, similar to the approach used in [2]. Subsequently, we will aim to make the description more realistic by incorporating biodiversity data akin to that presented in [3].

This internship does not require prior knowledge of agricultural systems but rather a strong curiosity about steering our agricultural sector towards sustainability. Good modeling and numerical (Python) skills are advised.

References

[1] E. Moretti and M. Benzaquen. Mitigating farmland biodiversity loss: A bio-economic model of land consolidation and pesticide use. *arXiv preprint 2407.19749*, 2024.

[2] V. Martinet and L. Roques. An ecological-economic model of land-use decisions, agricultural production and biocontrol. *Royal Society Open Science*, 9(10):220169, 2022.

[3] L. Mouysset, L. Doyen, F. Jiguet, G. Allaire, and F. Leger. Bio economic modeling for a sustainable management of biodiversity in agricultural lands. *Ecological Economics*, 70(4):617–626, 2011.