Campagne 2020 Contrats Doctoraux Instituts/Initiatives

Proposition de Projet de Recherche Doctoral (PRD)

Appel à projet ITE - Institut de la Transition Environnementale 2020

Intitulé du Projet de Recherche Doctoral : Adaptagro: Adaptation and mitigation in agricultural production systems during climate change.

Directeur de Thèse porteur du projet (titulaire d'une HDR) :

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Unité de Recherche :
Intitulé : Institut d'écologie et des sciences de l'environnement de Paris
Code *(ex. UMR xxxx)* : UMR7618

Ecole Doctorale de rattachement de l'équipe & d'inscription du doctorant : ED227-Sciences vie homme : évolution

Doctorants actuellement encadrés par le directeur de thèse (préciser le nombre de doctorants, leur année de 1ere inscription et la quotité d'encadrement) : 0

Co-encadrant :

NOM : **Robert** Prénom : **Corinne**
Titre : Chargé de Recherche ou HDR ☐
e-mail : corinne.robert@inrae.fr

Unité de Recherche :
Intitulé : Écologie fonctionnelle et écotoxicologie des agroécosystèmes
Code *(ex. UMR xxxx)* : 1402

Ecole Doctorale de rattachement : **Choisissez un élément :**
Ou si ED non Alliance SU : **ABIES doctoral school**

Doctorants actuellement encadrés par le co-directeur de thèse (préciser le nombre de doctorants, leur année de 1ere inscription et la quotité d'encadrement) : 0

Cotutelle internationale : ☒ Non ☐ Oui, précisez Pays et Université :

Description du projet de recherche doctoral ***(en français ou en anglais)***
3 pages maximum – interligne simple – Ce texte sera diffusé en ligne

Détailler le contexte, l'objectif scientifique, la justification de l'approche scientifique ainsi que l'adéquation à l'initiative/l'Institut.
Le cas échéant, préciser le rôle de chaque encadrant ainsi que les compétences scientifiques apportées. Indiquer les publications/productions des encadrants en lien avec le projet.
Préciser le profil d'étudiant(e) recherché.

Context

Climate change is a major challenge for the socio-ecological resilience of agricultural production systems (**APS**, Rosenzweig & Hillel 2015). Crop pests and pathogens respond strongly to events such as droughts, heat waves, and changes in temperature and rainfall patterns. It is widely recognized that climate change will impact the distribution and abundance of crop diseases (Chakraborty & Newton 2011, Juroszek & von Tiedemann 2013). Crop disease dynamics also depends on the spatial organization of the agricultural landscape and on cultural practices (Bargues-Ribéra & Gokhale 2020). In the Anthropocene, all these are affected by human decisions and therefore integral parts of our strategies to control crop loss.

Whereas our policies can change rapidly within a generation and the prevalence of certain crops as well, the short generation time of many pests and pathogens allows them to evolve in response to our decisions, and potentially escape control (Précigout et al 2017, 2020). Adapation in APS therefore consists of adaptive management and adaptation policies which control evolutionary adaptation by pests and pathogens (McDonald & Linde 2002, Gilligan 2008, Bousset & Chèvre 2013, Zhan et al 2015, Van Dooren 2019). The spatial and temporal distribution of crops at the landscape level could be a key to base agricultural climate adaptation and mitigation on (Loeuille et al 2013), if one could choose a spatial configuration of fields and the biodiversity they contain that enhances the resilience of the agroecosystem (Altieri et al. 2015). Also, public adaptation policies could drive farmer's adaptive management decisions, to obtain these landscape configurations. To avoid excessive crop loss, choices must anticipate the eco-evolutionary dynamics of pests and pathogens. Integrating disease eco-evolutionary dynamics, crop adaptive management and adaptation policies in predictive models is a critical next step in developing climate change adaptation and mitigation strategies for agroecosystems (IPCC 2014, Van Bruggen et al 2015). We accept the challenge of modelling socio-economic and eco-evolutionary dynamics jointly and anticipate that the modelling outcomes might demand a transition towards new policies for these ecosystems.

Objectives

- This PhD project will model the effect of climate change and landscape configuration on crop loss in a crop x pathogen eco-evolutionary model.
- This model will be extended so it can model different policies affecting farmer adaptive management decision rules, thus producing a socio-ecological model of the agro-ecosystem.
- Using the complete model, we aim to find adaptive and sustainable mitigation policies in terms of policies for landscape organization and crop diversity and with the aim to obtain resilient agro-ecosystems. These policies will anticipate adaptive management by farmers and evolutionary adaptation by the pathogens.

The modelling framework and output will be a useful tool for testing different policy scenarios and for testing sustainable mitigation strategies based on landscape configuration and crop diversity (Van Bruggen et al 2015).

Approach

We will focus on fungal pathogens of wheat while developing a generic modeling method that could apply to other crop/pathogen pairs. Our approach will extend the models developed by Précigout et al (2020).

The eco-evolutionary core of the model will describe the population and evolutionary dynamics of the pathogen in dependence on the spatial arrangement of the crop and farmer practises such as fertilization within and between years. We will investigate how climate change scenarios with different speeds of change will affect the evolutionary dynamics of the pathogen. This will involve an assessment of adaptational lags in pathogen traits (Van Dooren 2019), which assess how far traits are at any point in time from equilibria of their adaptive dynamics, which is an approximation of their evolutionary dynamics.

Précigout (2018) has shown that evolutionary adaptation can imply that pathogens remain generalists and don't become specialists of crops. In this case, adaptational lags are disadvantageous and policies and management should aim for adaptation of the pathogens.
A framework for simulating agro-ecological and social dynamics in a spatially explicit framework includes ecological, epidemiological and socio-economic sub-models. It allows simulating disease development at the landscape scale taking into account the following aspects: (1) farm-level crop and pathogen dynamics; (2) landscape configuration; (3) choices of the farmers in terms of cultural practices. We created such a framework in NetLogo, which is a friendly platform for coding multi-agent models (Tisue and Wilensky 2004). We will incorporate adaptive management by the farmers into it. Farmers can choose their cultural practices with different attitudes: maximizing profit, minimizing risks, or having a cooperative collective behavior (Edwards-Jones 2006). We will model these different attitudes and their responses to (1) changes in the farm ecosystem due to climate change and (2) changes in adaptation policies implemented on a larger scale. The model is now used to compare effects of the spatial distribution and composition of polyculture vs monoculture, for different climate scenarios on the occurrence of epidemics and to study the resilience of the agroecosytem during a 20 to 50 year period in terms of epidemics and crop production (Robert, Precigout, Sanner et al. in prep).
The complete model is very modular such that sub-models can be analysed separately and stepwise. We will use the complete modelling framework to investigate the trade-off between scenarios where policies aim towards maximization of yield and maximization of robustness against the spread of diseases. There will be three types of adaptation going on in the system: (1) evolutionary adaptation of the pathogen, (2) adaptive control or adaptive management via farmer behaviour (3) adaptation policies (Van Dooren 2019). The first is a major topic in evolutionary biology, the second a recurring theme in ecology which remains underdeveloped to date, the third is specific to climate change policies.

Innovation and relevance for SU-ITE
Several models of environmental effects on pathogen epidemics and crop loss have been developed at the level of a single field (Robert et al 2004, Robert et al 2008, Garin et al 2014, Juroszek & von Tiedemann 2013or at the landscape scale (Papaix et al 2014). Some models specifically modeled the effect of climate change on epidemics (Van Bruggen et al 2015). Simulations of crop pathogen evolution in response to pesticides (Marshall et al 2009) and more recently to crop fertilization (Précigout et al 2018, 2020) have also been developed and models of farmer behavior in terms of their agricultural decisions such as the adoption of new technologies (e.g., polyculture, input-poor practices Edwards-Jones 2006). Novel in our approach is that we will combine components of previous models to arrive at a versatile predictive tool. Next to that, we consider adaptation to climate change in every known sense (1) evolutionary adaptation by gene frequency change (2) the immediate (plastic) adaptive decisions of (rational) agents, (3) adaptation as a policy. Moreover, we apply it to a highly relevant issue, that of the climate resilience of our agroecological system.
The project is challenging. It is now widely recognized that the culture-nature separation is rather artificial. By contrast, the concept of socioecological systems (SES, Holling, 2001) paves the way to new theory on the dynamics of such coupled systems which are generally recognized to be complex, adaptive systems (Ollson et al 2004). This project will contribute to developing generic theory based on our expertise in general eco-evolutionary theory, coupled to knowledge of specific SES. It will also develop operational definitions to quantify the resilience and adaptive states of such systems (Folke 2006, Van Dooren 2019). Evolutionary dynamics does not need to approach adaptive dynamics solutions, which is therefore insufficient as a framework.
This project fits the mission of the SU Institute for the Environmental Transition very well. It is interdisciplinary by nature as demanded by the issue at hand and it can enable a closer cooperation of the scientific community with societal stakeholders, where it can serve as a basis for discussing real initiatives

and actions. The behaviour of individual farmers and public policy are rarely taken into account in eco-evolutionary modeling studies (Van Bruggen et al 2015).

Time Plan

Year one: Literature study, update of the project context. Model the impact of climate change and landscape crop heterogeneity on pathogen dynamics and crop loss in a crop x pathogen eco-evolutionary model. Model adaptation of the pathogen to environmental change. Redaction first manuscript.

Year two: Determine criteria and find adaptive and sustainable mitigation strategies in terms of landscape crop organization, agricultural behavioral practise and public policies for the model of year one. Redaction of second manuscript.

Year three: Use the modelling framework and output to test different policy scenarios for agricultural changes. Redaction of third manuscript. Completion and defense of PhD thesis.

Roles of the supervisors

Tom Van Dooren (TVD) and Corinne Robert (CR) will jointly recruit the most suited candidate. TVD will train the student in eco-evolutionary dynamics and CR in crop-pathogen modelling. Both supervisors will assist the student with model development and its implementation in a simulation. This will benefit from the presence of Pierre-Antoine Précigout in the team of CR. Both supervisors will assist the student with writing in English. TVD will take care of administrative tasks concerning the project and will provide a comfortable working environment where the student can perform well. He will assure funding for participation in activities of the ED227 and GDR Plasphen and for participation in scientific meetings. The candidate can benefit from research collaborations in the ongoing TRAVERSéES (2010-) project (PI CR) which aims to identify pathways for socio-agricultural systems to arrive at reduced pesticide use; and hopefully the ANR UNIC project which is being auditioned and where CR is one of the two PI's and TVD participant. Computer and computing facilities will be provided. TVD takes responsability that the time plan will be respected or will propose restructuring to complete the PhD within the imposed time constraints.

Profile of the candidate

The candidate has a keen interest in the environmental transition and is interested in agroecology or agro-eco-evolution. She/he has a proven experience in modeling and computing. He/she is eager to learn and can work both independently and in a team. The candidate can assume responsability for the recommendations based on the research by the end of the project. She/he has familiarity with writing in English.

Publications of the supervisors related to the project

Lassalle L (2020) Diversity within: Consequences of individual phenotypic variability on ecological and evolutionary dynamics. PhD Thesis, Chapters four and five.
https://dare.uva.nl/search?identifier=b1b89f76-e93f-4b98-b630-2ae18ef9521c

Le Gal A, Robert C Accatino, Claessen D, Lecomte J (2020) Modelling the interactions between landscape structure and spatio-temporal dynamics of pest natural enemies: Implications for conservation biological control. Ecological Modelling 420: 108912.

Précigout PA, Claessen D, Robert C (2017) Crop fertilization impacts epidemics and optimal latent period of biotrophic fungal pathogens. Phytopathology 107: 1256-1267.

Précigout PA, Robert C, Claessen D (2020) Adaptation of biotrophic leaf pathogens to fertilization-mediated changes in plant traits: A comparison of the optimization principle to invasion fitness. Phytopathology.

Rueffler C, Metz JAJ, Van Dooren TJM (2013) What life cycle graphs can tell about the evolution of life histories. Journal of mathematical biology 66: 225-279.

Van Dooren TJM (2019) Adaptational lags during periods of environmental change. bioRxiv, 742916.