Co-production of knowledge, tools and solutions for agroecological weed management

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1 Introduction

Weeds are considered to be a major hindrance to reduced pesticide use. They are highly damaging to arable crop production but to date, no non-chemical curative weed-control option as efficient as herbicides is available. Because each weed plant can produce hundreds or thousands of seeds which survive for several years in the soil, weeds must be managed at the rotation scale to limit damage to the current and following crops. In our landscapes, weeds are also are essential for biodiversity, in particular because they host and feed other organisms (such as pollinators), among which auxiliaries regulating other crop pests.

Weed management must therefore undergo a major paradigm shift, from a single simple highly efficient cropping technique (i.e., herbicides) to a combination of multiple, partially efficient, and interacting techniques. In other words, from cure to prevention, from chemical obliteration to biological and mechanical regulation, and from single-minded control to reconciling damage and benefits resulting from weeds. To make these new weed management strategies efficient and acceptable to farmers, they must be adapted to the pedoclimatic and socio-economic specificities of their farms.

Agroecological weed management thus requires (1) a better knowledge on biophysical processes driving weed dynamics in agroecosystems, particularly in relationship to the various management techniques, and the resulting impact on crop production and biodiversity, (2) synthesizing this knowledge as simulation models and decision-support systems to allow farmers and other stakeholders to evaluate many possible combination of management techniques in different pedoclimates to find the solutions adapted to their local context, (3) conduct these research and design tools and solutions together with farmers and crop advisors to ensure operationability and adoption.

To reach this goal, our team chose to work with a mechanistic process-based model to (1) identify knowledge gaps and organize research, (2) synthesize existing knowledge and produce emergent knowledge on agroecological levers, (3) mobilize this knowledge to cropping-system design, and (4) transfer research-based knowledge to stakeholders.

2 A virtual-field model to organise research and synthesize knowledge

The Dijon team started developing the FLORSYS simulation model twenty years ago (Colbach *et al.*, 2021). It is to date the most complete model in terms of crop management techniques and weed impacts.

Its inputs are a detailed list of cultural operations over several years (crop succession including cover crops and crop mixtures, management techniques), together with daily weather data, soil characteristics and a regional weed species pool. The model was designed to simulate biophysical processes that are essential for non-chemical crop management techniques and biological weed regulation in particular. Detailed biophysical model outputs allow understanding the performance in terms of crop production and biodiversity of a given crop, management technique or cropping system.

This model evolves over time depending on stakeholders' questions and the changing context (legislation, climate, etc.). At present, our team is running experiments in controlled conditions, in experimental stations and in farmers' fields to (1) understand processes such as plant-plant competition for water (because of climate change) or weed seed predation (its role for biological weed regulation, particularly in untilled fields), and (2) assess innovative management techniques such as fertilising only crop rows (to reduce nitrogen available to weeds in interrows) or mowing above the crop canopy (to limit weed seed production).

3 Tailor the model structure to stakeholders' requirements

Together with farmers and crop advisors, the detailed model outputs were aggregated into indicators of crop production as well as weed benefits and harmfulness to simplify the multicriteria comparison of cropping systems. To facilitate decision support, FLORSYS was used as a virtual farm-field network, simulating several thousands of cropping systems. The resulting simulation outputs were aggregated into a faster and easier-to-use metamodel (DECIFLORSYS) using machine learning techniques. This decision-support system was designed together with farmers and crop advisors to identify what it should do, with which information it should be fed and how its outputs should be presented. Other decision-support systems (e.g., OdERA) are presently being improved thanks to FLORSYS simulations, showing the model's importance for synthesising knowledge and making it available to different stakeholders.

4 Co-design cropping systems and crop ideotypes for weed management

These models are used by and with different stakeholders to increase our understanding of how the agroecosystem and, particularly, biological weed regulation works and to evaluate and design multi-performant cropping systems for agroecological weed management. In particular, we use the models to evaluate and promote the benefits of spatial and temporal crop diversification (intercropping, variety mixtures, cover crops, diversified rotations) for agroecological weed management, by (1) identifying crop ideotypes by simulating existing and virtual (randomly constructed) crop varieties in contrasting cropping systems, (2) tracking crop-diverse solutions in farm-field networks by simulating cropping systems identified in farm surveys and agricultural data bases, (3) evaluating crop-diverse solutions proposed by experts and stakeholders to identify cropping systems and design-rules optimised for different objectives and constraints, (4) running large-scale simulation studies aiming to establish rules for agroecological cropping systems (e.g., decision rules for false seed bed techniques depending on field history and recent weather) or indicators for risk assessment in fields (e.g., estimate weed soil seed bank from field history and observed weed flora), and (5) feeding participatory workshops with farmers aiming to reduce herbicide use. In addition to expert knowledge, farm data and data bases, these approaches use a large range of statistical methodologies and algorithms, among which classification and regression trees to build decision trees as well as optimisation algorithms to identify sets of solutions reconciling contrasting objectives and constraints. The case studies demonstrated that the benefits of crop diversification depend on the production situations and cropping systems, and thus showed the need for flexible rules on crop diversification and the usefulness of models to establish these rules.

5 References

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