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▶ **To cite this version:**

Nathalie Colbach, Frédérique Angevin, Aurélie Baquet, Nicolas Cavan, Floriane Colas, et al.. FLORSYS: A mechanistic model bridging scientists, advisors and farmers for designing agroecological weed management. International Crop Modelling Symposium (iCROPM 2026), iCROPM, Feb 2026, Florence, Italy. 4 p. ⟨hal-05661208⟩

HAL Id: hal-05661208

https://hal.science/hal-05661208v1

Submitted on 18 Jun 2026

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iCROPM FLORENCE 2026

3rd International Crop Modelling Symposium

Crop Modelling for Agriculture and Food Security under Global Change



February 2-4, 2026

Palazzo degli Affari
Florence, Italy



ORAL

SESSION 5 - DECISION MAKING AND INNOVATION SUPPORT

FLORSYS: a mechanistic model bridging scientists, advisors and farmers for designing agroecological weed management

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Keywords: 3D individual-based, ecological intensification, cropping system design, crop ideotypes, data mining

Introduction

Arable weeds are essential for biodiversity and highly damaging to crop production. So far, no non-chemical curative weed-control option used alone is as efficient as herbicides. Because their seeds survive for several years in the soil, weeds must be managed at the rotation scale to limit damage to the current and following crops. Weed management must therefore undergo a major paradigm shift, from a single highly efficient cropping technique (i.e., herbicides) to a combination of multiple, partially efficient, and interacting techniques. This shift requires a change of perspective from cure to prevention, from chemical suppression to biological and mechanical regulation, 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 conditions, production contexts and socio-economic specificities of their farms.

The objective of this paper was to demonstrate how a mechanistic process-based model was developed and used to co-design crop ideotypes and cropping systems for weed management, thus bridging the gap between research on biophysical processes and agroecological weed management in real-life farms.

Materials and Methods

The methodology comprises three steps: (1) experiments in controlled conditions, experimental stations and farmers' fields to understand biophysical processes that drive weed dynamics and impacts in agroecosystems, in relation to cropping techniques, (2) synthesize this knowledge into simulation models and decision-support systems to produce emergent knowledge on agroecological levers, (3) design cropping systems and crop ideotypes adapted to different goals and local contexts.

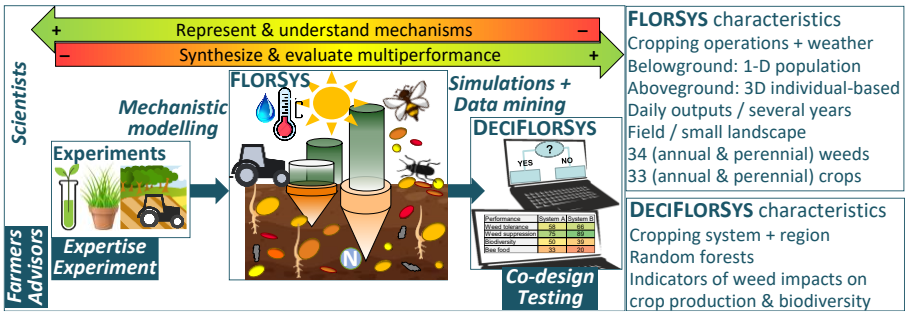


Figure 1. The modelling chain linking experiments, mechanistic modelling and decision-support systems for designing agroecological weed management strategies and the role of scientists, advisors and farmers (Colbach et al, 2021).

These steps were conducted with farmers and advisors to ensure the operational nature and adoption of weed management strategies. Step 1 uses mechanistic modelling to translate experimental results into equations and parameters for the FLORSYS simulation model (Figure 1). Step 2 uses FLORSYS simulations and data mining to co-design decision support systems. Step 3 uses these tools to evaluate and design crop ideotypes and cropping systems for agroecological weed management, with increasing degrees of farmer implication: (1) define the objective of the simulation study, (2) provide farm practices for simulations via surveys and agricultural databases (DEPHY), (3) propose prototypes for simulations, (4) iteratively design cropping-systems in participatory workshops. Latin Hypercube Sampling (LHS) was used to determine simulation plans, machine learning (classification and regression trees, random forests) to build decision trees and meta-models, and optimisation algorithms to identify solutions reconciling contrasting objectives and constraints.

Results and Discussion

The FLORSYS model to synthesize knowledge in a virtual experimental field. The FLORSYS simulation model started twenty years ago as a research tool (Colbach et al., 2021). Its inputs list all cultural operations in detail over several years, together with daily weather data (past or future), soil characteristics and a regional weed species pool. The 3D individual-based multispecies model simulates biophysical processes that are essential for non-chemical crop management and biological weed regulation. To tailor FLORSYS to stakeholders' requirements and to simplify the multi-criteria comparison of cropping systems, the detailed model outputs were aggregated into indicators of crop production and weed impacts on crop production and biodiversity, together with advisors and farmers. FLORSYS has evolved over time to account for stakeholders' questions and the changing context, recently adding (1) processes such as plant–plant competition for water (to include tropical conditions and climate change), weed seed predation and vegetative reproduction of perennial weeds (which increase in conservation agriculture), (2) species and varieties to evaluate crop diversification, (3) innovative management techniques (e.g., topping, agroecological infrastructures).

Use FLORSYS to co-design decision support systems. FLORSYS was used as a virtual farm-field network, simulating thousands of cropping systems with different soils and weather records. The simulation outputs were used to check and improve existing decision-support systems, e.g., whether OdERA (https://www.agro-transfert-rt.org/outils/odera/) was fit for climate change. But FLORSYS's importance for making process-scale knowledge available to different stakeholders was best illustrated with the development of DECIFLORSYS. This faster and easier-to-use metamodel was built from FLORSYS simulations using machine learning techniques. DECIFLORSYS was co-designed with farmers and crop advisors via surveys and participatory workshops testing successive versions to identify (1) key functions, applications and input/output formats, and (2) how to shift stakeholders' weed perception from eradication (focusing on weed abundance) to agroecological management (based on weed impacts).

Co-design cropping systems and crop ideotypes. The ideotypes and ideal systems identified from simulations based on LHS plans and optimization algorithms were often very different from existing varieties and cropping systems. Key

techniques and rules for combining them were identified, showing that the best 0-herbicide systems with well-timed false-seed-bed operations and occasional mouldboard ploughing had a weed-caused yield loss of only 4%. These results and rules were then used to accompany farmers in participatory workshops to design new cropping systems.

Conclusions

FLORSYS complements field experiments and local expertise via long-term simulations with different climate scenarios, disentangling the effects of correlated practices and predicting the effects of interacting techniques as well as giving access to difficult-to-measure state variables on soil, crops and weeds needed to understand how the agroecosystem functions. The benefits, crop ideotypes and optimal agroecological cropping systems depended on the production contexts and the scale (field vs farm vs landscape, year vs rotation) at which objectives should be reconciled. Flexible rules are thus required to account for local specificities as well as models to establish these rules.

Acknowledgements

Major recent funding sources: COPRAA funded by Office Français de la Biodiversité, Mix-it! funded by the Swiss Federal Office for Agriculture (BLW), Horizon Europe IntercropVALUES (N°101081973)

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