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COLLABORATIVE PROJECT

AMIGA
Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

D7.4 Adaptation of FlorSys to maize cropping systems

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Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Summary

The present deliverable is part of Task 7.3 "**Design of exposure and hazard models to assess the interest of predictive models to drive PMEM by identifying hotspots situations". In order to** assess to what extent exposure-hazard models may help risk managers set up efficient monitoring schemes, this task considers two specific crop-trait-pest situations:

- Design of a spatially-explicit exposure model to assess the impact of *Bt* maize on the mortality of non-target Lepidoptera;
- Effect of cropping systems and of herbicide management regimes on weed abundance and diversity.

For the second case study, AMIGA has been using the existing generic FLORSYS mechanistic model that allows assessing the impacts of cropping systems on weed diversity and has extended it to take account of maize-based cropping systems and their specific weed flora.

The report presents the steps carried out to adapt FlorSys to maize cropping systems:

- Parametrization of maize weed species;
- Introduction of additional biodiversity indicators;
- Upscaling FlorSys from field to landscape;
- Prediction of weed resistance;
- Evaluation of FlorSys for maize-based cropping systems.

Introduction

The overall objective of the task 7.3 is to evaluate the impact of modifications in agricultural practices resulting from introducing GM maize into cropping systems on weeds and the subsequent implications on sustainability in order to help set up post-market environmental monitoring strategies. The weed dynamics model used in AMIGA is FLORSYS (Colbach et al., 2014b; Gardarin et al., 2012; Munier-Jolain et al., 2013) which is to date the only multispecies model that predicts the effects of most cropping system components and pedoclimate.

The structure of FLORSYS is described in detail in previous papers (Colbach et al., 2014a; Colbach et al., 2014b; Gardarin et al., 2012; Munier-Jolain et al., 2014; Munier-Jolain et al., 2013). The input variables of FLORSYS consist of:

- the above-ground climate (evapotranspiration, radiation, temperature, rainfall and radiation) for each simulated day;
- a description of the simulated location: soil texture and depth as well as latitude;
- the initial weed seed bank (i.e. seed density for each weed species and for each cm soil down to 30 cm);
- the cropping system during the whole simulated period, comprising the crop sequence including cover and undersown crops, the date of all operations (e.g. sowing, harvest) and their characteristics (e.g. sowing density, depth, pattern and crop variety for a sowing operation).

The heart of FLORSYS is a generic life-cycle consisting of a succession of life-stages chosen for their interaction with cropping system components and light competition.

The first version of the FLORSYS model was developed at the field scale; it quantified the effects of cropping systems (crop succession, cultural techniques) and pedo-climatic factors (weather, soil texture) on the annual life-cycle of weeds (seed survival, dormancy, germination, plant emergence, light interception, biomass accumulation, seed production) and was initially parameterized for weed species emerging in autumn and in early spring. There were therefore several aspects that needed to be adapted before FlorSys could be used for AMIGA purposes:
- parametrize maize-related weeds and introduce them into FLORSYS;
- add a Lepidoptera indicator to an already existing series of indicators related to production effects and impacts on biodiversity;
- make it possible to use FLORSYS at the landscape level;
- model weed resistance to glyphosate;
- evaluate FLORSYS in the context of maize cropping systems.

1/ Parametrization of FlorSys for maize

FlorSys needed to be adapted to consider those weeds more frequently observed in maize and/or in margins along arable fields in several European regions. Table 1 summarizes the additional weeds that were considered by AMIGA.

Experiments (Compayre, 2012)

Two experiments were set up with additional weed species typical of maize in order to estimate parameters determining the species ability for competition:
- initial seedling vigour and growth;
- characterization of plant morphology according to shading intensity during their life-cycle.

a. Initial seedling vigour (greenhouse conditions).

Weed seeds were prepared, sown in small pots (see figure 1) and monitored over time. Two methods were used to measure the leaf area:

- a destructive one which consisted in measuring plant height and diameter as well as leaf area with a planimeter;
- a non-destructive method that estimated leaf area from photos taken regularly during the experiment, and further analysed with the VISILOG software.

These measurements resulted in the estimation of the initial plant leaf area, their specific leaf area, and their relative growth rate. Out of 12 species, only 9 could be fully parametrized as germination could not be obtained for the other three.

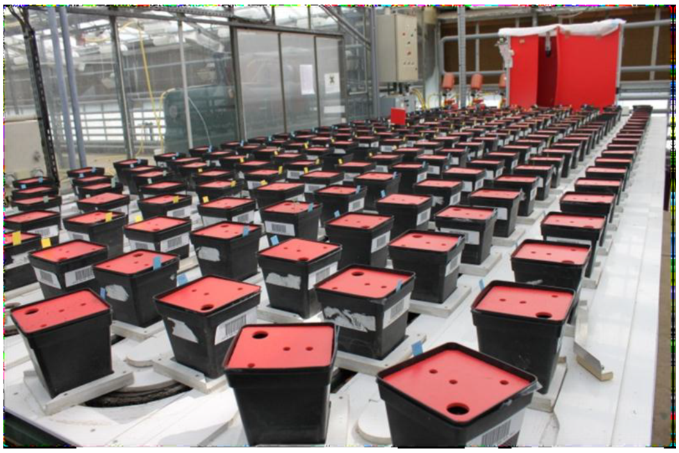

Figure 1. Preparation of pots for weed experiments.

Common name	Latine name	Bayer code
Velveleaf	*Abutilon theophrasti*	ABUTH
Jimsonweed	*Datura stramonium*	DATST
Hairy finger grass	*Digitalis sanguinalis*	DIGSA
Mercury	*Mercurialis annua*	MERAN
Millet	*Panicum miliaceum*	PANMI
Bluegrass	*Poa annua*	POANN
Foxtail	*Setaria viridis*	SETVI
Chamomile	*Matricaria perforata*	MATIN
Speedwell	*Veronica hederifolia*	VERHE
Fluvellin*	*Kickxia spuria*	KICSP
Violet*	*Viola arvensis*	VIOAR
Wild radish*	*Raphanus raphanistrum*	RAPRA

Table 1. Weed species experiments. * Species which did not grow properly

b. Variability of plant morphology as a consequence of shading (semi-field experiment)

The same weed species were studied here to assess the effect of shading (mimicking the effect of competition between maize and its weed species). Plants were first prepared on so-called Quicksplot trays (see figure 2) and then transferred to the field under shaded or not conditions.

Figure 2. Quicksplot trays used to assess the effect of shading on weeds.

Results

Figure 3 presents the estimation of initial weed growth for some of the studied species (Leaf area as a function of degree-days). Table 2 gives the estimated figures for the same species.

Species (Bayer code)	Initial leaf area cm²	Relative Growth Rate RGR	Seed weight (mg) basis LEDA	Specific Leaf Area cm²/g
Abuth	0,2199	0,0315	6.5	269.05
Maïs	0,6448	0,0402	252	397.13
Matin	0,0175	0,0147	0.35	474.70
Panmi	0,2231	0,0331	3.78	275.11
Poann	0,0449	0,0145	0.37	167.03

Table 2. Results of experiments on weed development.

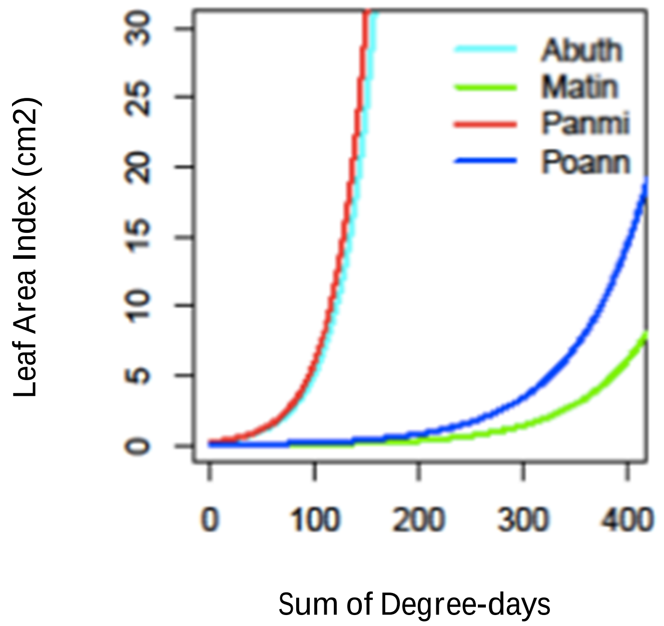

Figure 3. Evolution of Leaf Area Index as estimated with the parameters observed in experiments.

2/ Introduction of additional indicators:

In a prior study, the weed densities simulated by FLORSYS were translated into a set of indicators depicting services and disservices of the agroecosystem. The first four indicators reflect the weed harmfulness for crop production (Mézière et al., 2014): (1) crop yield loss, (2) harvest pollution by weed seeds, stems and leaves, (3) harvesting problems due to green weed biomass blocking the combine, and (4) field infestation represented by weed biomass averaged over cropping seasons.

Two of the indicators for weed contribution to biodiversity (Mézière et al., 2014) reflect the contribution to vegetal biodiversity: (1) species richness, i.e. the number of weed species present during the cropping seasons, and (2) Pielou's index for species equitability, i.e. the dominance of the weed flora by one or a few species. The other three indicators appraise weeds as a trophic resource for other organisms in the agro-ecosystems, considering the seasons of activity and food shortage: (3) the number of weed seeds present on soil surface in autumn and winter to feed field birds (Marshall et al., 2003; Wilson et al., 1999) (4) lipid-rich seeds on soil surface in summer to feed insects such as carabids (Trichard, pers.communication), and (5) weed flowers in spring and summer to feed domestic bees (Ricou et al., 2014; Wratten et al., 2012).

During the AMIGA project (and in collaboration with another research project[1]), a new biodiversity indicator was developped for assessing weed contribution to feeding Lepidoptarea. During a student project financed by the companion project (Meyer, 2014), weed flowers were ranked according their attraction for lepidopterae, based on petal flower, nectar amount and appetance. These species coefficients are used to weight weed flower densities simulated by FLORSYS in a linear combination similar to that developed by Mézière et al (Mézière et al., 2014).
These indicators are then used to evaluate current and prospective maize cropping systems in terms of weed impact on crop production and biodiversity.

3/ Prediction of weed resistance

The introduction of herbicide-tolerant (HT) genetically-modified (GM) crops has been reported to favour the selection of glyphosate-resistant weeds. When these crops are introduced into cropping systems, they also change agricultural practices other than herbicides, often resulting in simplified rotations and tillage. These changes can mitigate or amplify the risk of herbicide resistance, and thus weed harmfulness for crop production as well as weed contribution to biodiversity.

We adapted the existing weed dynamics model FLORSYS to simulate the advent and progress of herbicide resistance by mutation, heredity, fitness costs and selection due to glyphosate applications and other cultural practices. This was done by simulating three populations (wild, heterozygous with one resistance allele, homozygous resistant to glyphosate) for each weed species belonging to botanical families with reported glyphosate resistance (Colbach et al., 2015b; Fernier, 2014).
Parameters were estimated from literature. A sensitivity analysis was carried out, showing that weed dynamics were very sensitive to mutation rates and to which weed species could become resistant; the effect of selfing rate, fitness cost and glyphosate efficiency was negligible.

4/ Upscaling from the field to the landscape

The 3D representation of FLORSYS was modified to allow the simulation of non-GM buffer zones, unsown interfaces and grass strips around GM field centres. In practice, the landscape version of FLORSYS works as follows:

- each plot within a given landscape (GM field, non-GM fields, margins, buffer zones, etc) is simulated with the field version of FLORSYS (ran in parallel for each annual cycle);

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[1] Research programme “Assessing and reducing environmental risks from plant protection products” funded by the French Ministries in charge of Ecology and Agriculture

- A specific submodel, developed by AMIGA, simulates annual seed movements between spatial units, using the CaliFloPP algorithms (Bouvier et al., 2009):
    - parameterizing this submodel to quantify seed dispersal during seed shed is still ongoing work; .
    - no data have yet been found for seed dispersal due to agricultural machinery.
    - Seed migration by natural vectors is simulated with dispersal kernels based on literature (Thomson et al., 2011; Thomson et al., 2010)

Also, FLORSYS was made compatible with and introduced into the INRA modelling platform RECORD (https://www6.inra.fr/record_eng/Presentation) to allow parallel simulations of different fields and/or semi-natural habitats

5/ Evaluation of FLORSYS

After the adaptation of FLORSYS to maize cropping systems, its evaluation was carried out by comparing FLORSYS simulations to independent field observations in order to determine the domain of validity and the prediction error.

Field datasets were compiled from two long-term system experiments comparing different crop management regimes at INRA Dijon and INRA Versailles (Colbach et al., submitted). FLORSYS generally satisfactorily predicted weed seed bank, plant densities and crop yields, both at daily and multiannual scales. It overestimated plant biomass and underestimated total flora density. Several missing processes were identified, photoperiod dependency in flowering, summer-emerging weeds, crop-weed, competition for nitrogen, and weed dynamics in untilled fields. Guidelines for model use were proposed. A patch for correcting flowering timing at Southern latitudes is now available.

Conclusion

The adaptation of FLORSYS to maize cropping systems was considered satisfactory to make it possible to assess, by simulation, the impact (resistance evolution, impact on farmland biodiversity) of introducing GM-based cropping systems into various European agroecosystems and, consequently, help drive the monitoring schemes that risk managers should put in place. The outcomes of simulation studies are reported in the specific report D7.5 “Report on the potential use of exposure-hazard models to optimize monitoring sampling schemes ».

Additional reports and publications

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Fernier A. (2014) Evaluation of glyphosate resistance risk (in French). Trainee report, *Master 1, AgroParisTech, Paris, France*, 25 p. + annexes

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