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META-MODELING LIGHT INTERCEPTION IN CROP: WEED CANOPIES

Floriane COLAS¹ – Jean-Pierre GAUCHI² – Jean VILLERD³ – Nathalie COLBACH¹

¹ INRA, UMR1347 Agroécologie, 21000 Dijon, France, Email: floriane.colas@dijon.inra.fr

² INRA, UMR MaIAGE, Université Paris-Saclay, 78350 Jouy-en-Josas, France

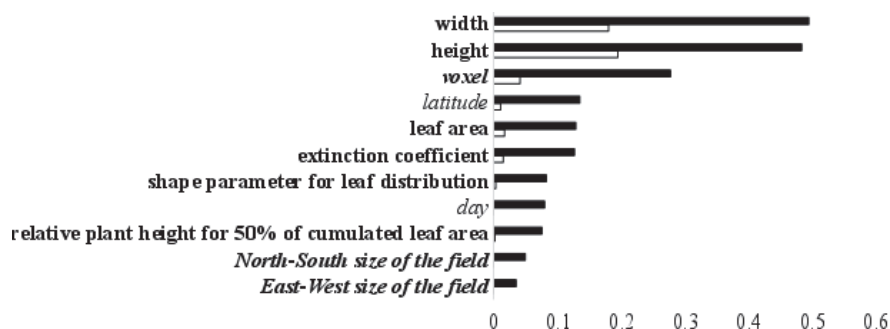
³ INRA, UMR1121 LAE, Nancy Université - INPL, 54505 Vandœuvre-lès-Nancy, France

Introduction

Weeds are a major pest of crop production but are important for biological diversity. In order to design cropping systems that reconcile crop production and biodiversity we need tools that allow us to test multiple cropping systems, such as FLORSYS (Colbach *et al.*, 2014). This mechanistic, multi-annual and multi-specific model ("virtual field") represents the crop:weed canopy in 3D, with an individual-based light interception sub-model (Munier-Jolain *et al.*, 2013), which is time-consuming and thus limits the number of tested cropping systems. The 3D canopy is discretized with voxels (3D pixels), and each plant usually consists of several voxels. Photosynthetically Active Radiation interception (PARi) and absorption (PARa) are calculated for each voxel, and then summed for each plant. Here, our objective was to accelerate the sub-model by developing a meta-model predicting light interception and absorption directly at the scale of the plant.

Materials and Methods

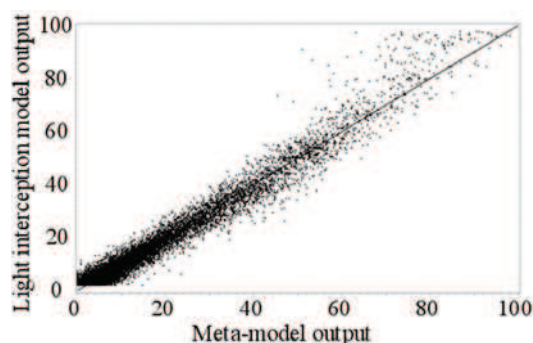
The light interception of a target plant depends on: (1) plant parameters (e.g. height, extinction coefficient); (2) physical environment (latitude, day), (3) model precision (voxel, field sample area), and (4) biological environment (density, location and parameters of neighbouring plants). We used a new global sensitivity method based on a truncated Legendre polynomial chaos expansion (PCE) whose coefficients are estimated by PLS regression (Gauchi *et al.*, 2016) to: 1, rank inputs as a function of their polynomial and total effects on outputs *via* the so-called PCE-PLS, and; 2, to provide a meta-model predicting PARi and PARa at the plant



level as a function of the four input types. The number of computer-based iterations required to build the meta-models were based on a space-filling design following a Sobol quasi-random sequence. For the meta-model, the canopy of target plants were aggregated into synthetic input variables (such as mean neighbour plant height, as opposed to actual input variables crop sowing pattern and weed density).

Results and Discussion

In isolated plants, target-plant characteristics are more important than physical environment or model precision for determining PARa (Fig. 1). Among the former, the variables determining the volume occupied by the target plant (height, width) dominate all others. The PARa meta-model consisted of a partial Legendre polynomial of



4000 monomials of degree 7; presenting a high predictive quality (Fig. 2), with an index Q^2_{cum} of 0.95 (a specific PLS fitting-prediction criterion which should be close to 1). The results for target plants inside canopies will be available soon.

Figure 1. Sensitivity index sensu PCE-PLS, in white polynomial effect (i.e. with no interactions), in black total effect of the inputs (**plant parameters**, physical environment and **model precision**).

Figure 2. Scatter plot of the meta-model predictions and the light interception sub-model outputs.

Conclusions

The sensitivity analysis allowed us to discriminate those plant variables that must be predicted precisely (e.g. plant height) from those that can be estimated with less precision (e.g. leaf area distribution parameters). The meta-model reduces computation time without impairing prediction quality, which allows us to simulate numerous cropping systems and inform best-management practices and advice for farmers.

Acknowledgements

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FLORIANE COLAS¹, JEAN-PIERRE GAUCHI², JEAN VILLERD³, NATHALIE COLBACH¹

¹Agroécologie, AgroSup Dijon, INRA, Univ. Bourgogne Franche-Comté, F-21000 Dijon, France; ²MalAGE, INRA, Université Paris-Saclay, 78350 Jouy-en-Josas, France; ³INRA-Nancy Université-INPL, UMR 1121 LAE, F-54505 Vandœuvre lès Nancy, France

Weeds are harmful for crop production but crucial for biodiversity. To design cropping systems that reconcile crop production and biodiversity, we need tools that allow to test numerous and diverse cropping systems. FLORSYS¹ is a "virtual field" model that predicts weed dynamics in current and prospective cropping systems. It must be accelerated and simplified before it can be used to test weed management scenarios.

3D light interception sub-model

The 3D light interception sub-model³ (Fig 1) is a bottleneck and takes 71% of the computation time.

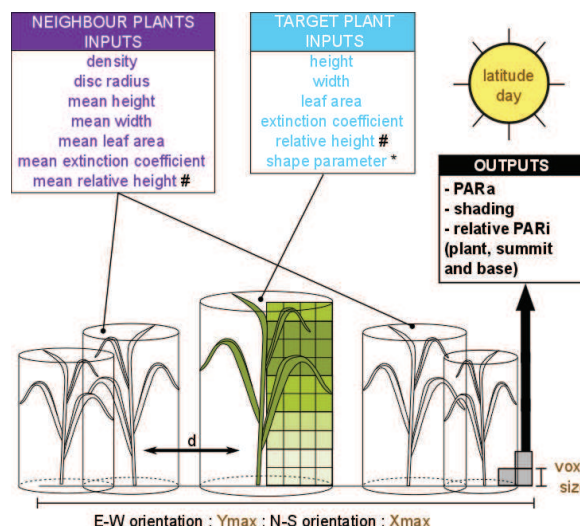
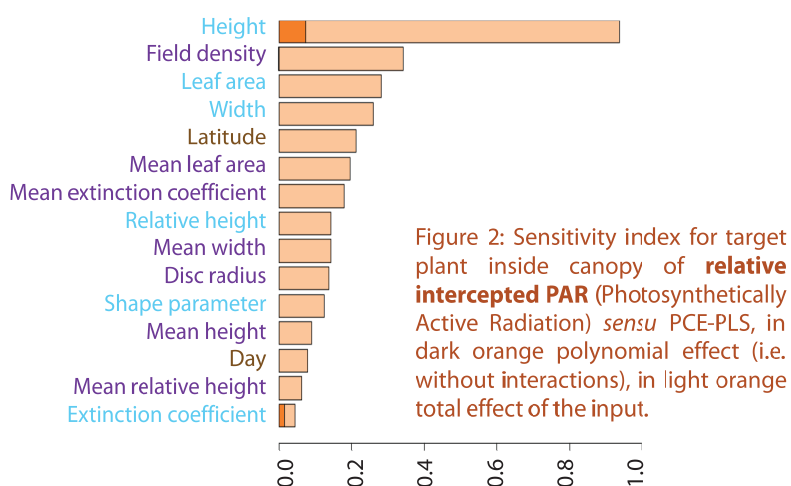
AIM: Meta-model the 3D light interception sub-model of FLORSYS

Sensitivity analysis and meta-modelling

We used truncated Legendre polynomial chaos expansion (PCE) whose coefficients are estimated by PLS regression (Gauchi et al., 2016) in order to:

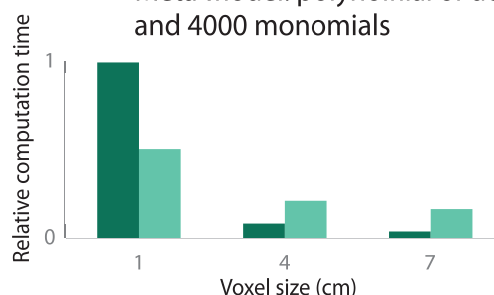
- Perform a **sensitivity analysis** by ranking correlated inputs as a function of their polynomial and total effects on outputs via the so-called PCE-PLS
- Provide a **meta-model** predicting outputs at the plant level

Sensitivity indices



Meta-model and simulation time

- Meta-model: polynomial of degree 7 and 4000 monomials



Discussion and conclusion

- Target-plant characteristics >> Physical environment
- Density >> Canopy structure variables
- Time saving thanks to the meta-model depend on the precision wanted (voxel size)
- Mechanistic models can be faster for complex, interactive processes than "empirical" meta-models
- The transformation of the statistical meta-model into a simulation meta-model for FLORSYS requires complementary algorithms (e.g. how close must a neighbour be to be included in the canopy inputs?).

FUTURE: Compare meta-models with FLORSYS and field observations to determine best use practices.