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Contents

From Detailed to Summary Models of the Crop-Soil System for Larger Scale Applications

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Crop growth models developed at field level are increasingly used in larger scale studies often in combination with other models to explore management options at the whole-farm scale or for integrated assessment at regional level (e.g. Giller et al., 2006; van Ittersum et al., 2008). Unclear is whether the mechanistic detail of dynamic simulation crop models is required for such applications or whether summary models may be sufficient. To address this issue and to identify relationships that need specific attention in future research, we compared simulations of crop production by two models with a different degree of mechanistic detail.

Methodology

The models considered are APES and FIELD. The crop module of APES (Agricultural Productivity and Externalities Simulator - Donatelli et al., 2007) was developed to simulate crop growth and production for the European agriculture. The crop module of FIELD (Field-scale resource Interactions, use Efficiencies and Long-term soil fertility Development - Tittonell et al., 2007) calculates crop production based on resource (light, water, nutrients and labour) availability on the farm, aggregated over a season. The crop module of FIELD summarises processes regulating resource utilisation in the form of functional relationships. For this study APES was calibrated for maize using leaf area index, date of flowering and physiological maturity collected at Bouillac, Midi Pyrenees, France during the years 1999 and 2000. APES was used to derive functional relationships for maize to be used in FIELD. Crop production was calculated with FIELD using these functional relationships. We compared yields predicted on the basis of radiation and water availability by these two models against measured data for the years 1999 and 2000 and compared yield predicted from both models for a time series from 1982 to 2006.

Results

The two years chosen for the calibration/testing of APES were 'average' years for the region, in terms of weather, with similar amounts of rainfall and radiation captured by the crop during the growing season (Table 1). Using APES we derived two relationships for the model FIELD, specific to Bouillac in Midi Pyrenees:

$$Y_l = I_{PAR} * F_{int} * \varepsilon_l \quad (1)$$

$$Y_{wl} = R_{cum} * F_{cap} * e_w \quad (2)$$

Where, Y_l is the light determined yield, I_{PAR} the incident photo-synthetically active radiation (PAR) received by a crop canopy over the growing season, $F_{int} = 0.5$ is the fraction of PAR intercepted by the crop over the season, derived for maize in Midi Pyrenees using APES, and $\varepsilon_l = 3.3$ g DM (dry matter) MJ^{-1}, the average (intercepted) radiation use efficiency over the season.

Y_{wl} is the water-limited yield, R_{cum} the amount of water (rainfall and irrigation) given to the plant during the growing season, $F_{cap} = 0.37$, is the water capture efficiency, or the fraction of the total water available (R_{cum}) that is transpired by the crop as derived with APES for maize in Midi Pyrenees. The coefficient $e_w = 10.24$ g DM m^{-2} mm^{-1} represents the transpiration conversion efficiency, i.e. the amount of biomass produced per mm of water transpired by the crop canopy over the growing season.

Figure 1 shows the yield predicted by both models compared with the observed yields at Bouillac for the years 1999 and 2000. Maize productivity was 8.4% lower in 2000 than in 1999, although average radiation and cumulative water available to the crop was almost similar in both years (Table 1). This lower productivity is due to the higher water stress during the grain filling period (less rain during this period) in the year 2000. A mechanistic crop growth model such as APES, simulating the dynamics of crop growth during the growing season is able to account for the effects of water stress during critical phases. APES simulated maize yields that were 26% lower in 2000 than in 1999, with yield differences with respect to measurements of +15% for the year 1999 and -7.2% for 2000. The summary model FIELD, which does not consider intra-season rainfall variability, simulated maize yields that were 13% larger for 2000 than for 1999, overestimated water-limited grain yields in the year 2000 by 16% with respect to measured yields.

Table 1: Radiation and water available for the crop during the growing season and water stress indexes experienced by a maize (calculated by APES) at Bouillac in 1999 and 2000.

	1999	**2000**
Incoming PAR (MJ m^{-2})	1602	1644
Available water for the crop (mm)	502	569
Average water stress index	0.15	0.19
Water stress index during grain filling	0.08	**0.40**

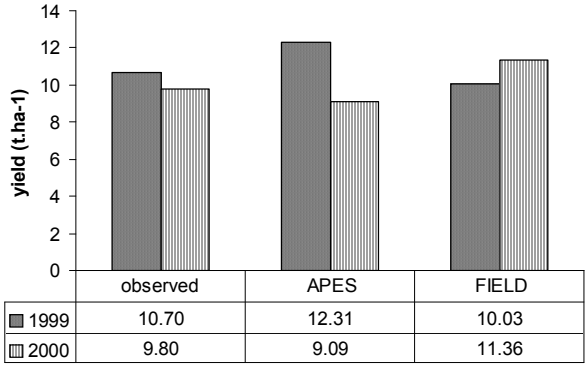

Figure 1: Comparison of models prediction with observed yield : Bouillac, Midi Pyrenees, France

Discussion and conclusions

Results from the simulation of water-limited maize grain yields in Midi Pyrenees over a 25 years period (not shown) indicate a difference of 20% between yields predicted by FIELD and APES. The advantages of summary models for farm and regional applications reside in that they require less data for parameterisation, once generic functional relationships have been derived for a certain region (cf. Equations 1 and 2). For exploration of medium- to long-term changes in crop productivity and soil quality such summary models may suffice (Bouman et al., 1996). However, the preliminary results of this study suggest that the intra-seasonal variability of resources such as water may have a noticeable effect on maize productivity (overestimation of 16% for water limited grain yield). Such an effect may be larger in situations without irrigation, when droughts coincide with pollination, or for maize genotypes of shorter cycles. On the other hand, this effect may be smaller for other crop types with a more spread reproductive period. Further analysis with longer time series are required (and are ongoing) to derive relationships that consider the effect of intra-seasonal rainfall variability in summary models to enable yield estimations at large scales.

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