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# Putting the coherence between crop processes and model inputs at the core of model development: a case study for water stress in intercropped systems

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## 1 Introduction

Modeling the dynamics of water stress is a recurrent issue for many crops, either for the quantification of yield gap due to water or for the management of Regulated Deficit Irrigation. The demand for such models increases especially for intercropped systems, but data required to build, parametrize and evaluate these models is limited. Moreover dealing with a diversity of agrosystems with one model highlights the questions of parametrization protocols and model uncertainty estimates. These aspects appear insufficiently handled by existing intercropped systems models.

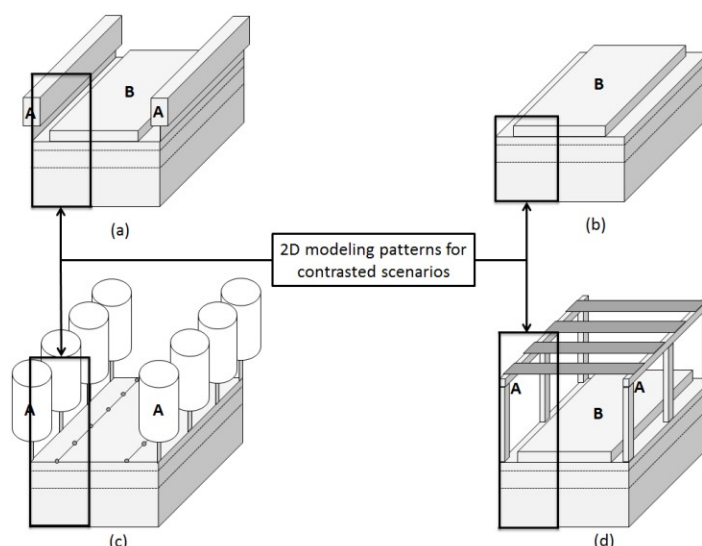
## 2 A modeling approach putting the coherence between crop processes and model inputs

We put the biophysical processes conceptualization and parametrization at the core of the model development by following several principles. Firstly, each model input has a functional relevance and refer to a biophysical process. This coherence between crop processes and model inputs opens the possibility to use expert knowledge to estimate parameters in situations where data are lacking while knowledge on plants and soils are rich. Secondly, parameter calibration is excluded, this procedure being both particularly demanding in data and potentially delicate when evaluating the predictive quality of the model. Thirdly, several protocols specifying how to get each model input are defined. These protocols take into account different accuracy levels depending on data availability and allow to assess the associated uncertainty in model outputs (Roux *et al.*, 2013). Fourthly, some critical model concepts are integrative in order to cover a range various intercropped systems while trying to contain both the potential error resulting from using simplified hypotheses and the parametrization error coming from using more detailed descriptions of crop processes.

## 3 Illustration of the modeling approach through the BIS\_Wat model development

We applied these principles to develop a new water balance model called BIS\_Wat (Bispecific Intercropped Systems – Water balance model) built to simulate the dynamics of water stress experienced by each crop of an intercropped system. This new model extends to others types of bispecific agrosystems the WaLIS model (Celette *et al.*, 2010) developed for intercropped vineyard. BIS\_Wat is a 2D bispecific tipping-bucket model working at a daily time step that is based on the Fraction of the Transpirable Soil Water (FTSW) concept (Sinclair & Ludlow, 1986) used as water stress indicator. The use of this generic concept allows to take into account both soil and crops characteristics for the transpiration regulation process. The soil is sampled into layers and columns with roots representation based on the effective rooting depth concept (Lacape *et al.*, 1998). Moreover, the model is based on three main hypotheses: i) homogeneity along the row and symmetry on either side of tree (useful to extrapolate results to field scale); ii) the four water fluxes which impact the water balance are soil evaporation, plants transpiration, surface runoff and deep percolation, implying that others water fluxes are neglected; iii) the evaporation and transpiration fluxes are directly driven by the intercepted radiation and by the soil water deficit experienced by plants, each plant of the association having its specific FTSW. Making explicit these assumptions allows to define a theoretical validity domain and ensure model transparency but evaluation on contrasted situations will lead us to define more precisely the model limits.

The use of integrative concepts allows to simulate both monospecific and bispecific systems for a wide range of crops in a Mediterranean climate. Consequently, it is theoretically possible to simulate with the model the water stress dynamics of contrasted agrosystems ranging from annual crop to intercropped orchards (Fig 1.). Two main concepts are at the core of the BIS\_Wat parameterization: the Radiation Interception Efficiency (RIE) and the Total Transpirable Soil Water (TTSW) for each of the associated species. These model inputs have to be set or not, depending on which kind of scenario is modelled (Table 1.).



**Fig. 1.** Example of 4 contrasted scenarios where A is the dominant crop or structure and B is the dominated crop for the radiation competition: (a) intercropped vineyard (b) durum wheat (c) irrigated peach orchards and (d) food crops under photovoltaic panels. For each example, the 2D modeling pattern is highlighted.

**Table 1.** Illustration of BIS\_Wat parametrization for 4 contrasted scenarios  
(0: model input not required; 1: model input required)

	Intercropped vineyard (a)	Durum wheat (b)	Irrigated peach orchards (c)	Food crops under photovoltaic panels (d)
TTSW (A)	1	0	1	0
TTSW (B)	1	1	0	1
RIE (A)	1	0	1	1
RIE (B)	1	1	0	1

#### 4 Conclusion and future work

We have presented several modeling principles to build specific crop model and a new model of bispecific cropping systems named BIS-Wat, putting at the core of the model development the model inputs and their coherence with crop processes. A possible model use would be to assess the level of water stress of each of the associated crop compared to a water stress target as defined for example in vineyards by (Pellegrino *et al.*, 2006). We have already verified that the model can be parametrized on various systems thanks to the choice of two central integrative inputs and made an evaluation on vineyards based on soil water content measurements. We are currently working on error level assessment on the four different systems described in Figure 1 (e.g. wheat, intercropped vineyard, salad and peach orchards) using quantitative metrics adapted to the diagnosis of water stress.

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