Evaluation of the STICS soil-crop model for modelling arable intercrops

Noémie Gaudio, Dominique Ripoche, Marie Launay, Hélène Tribouillois, Eric E. Justes

EVALUATION OF THE STICS SOIL-CROP MODEL FOR MODELLING ARABLE INTERCROPS

Gaudio Noémie[1*] *– Ripoche Dominique*[2] *– Launay Marie*[2] *–Tribouillois Hélène*[1] *– Justes Eric*[1]

[1] INRA, UMR 1248 AGIR, INRA-INP-ENSAT, F-31326 Castanet-Tolosan
[2] INRA, US 1116 Agroclim, F-84914 Avignon
[*] Noemie.Gaudio@toulouse.inra.fr

Introduction

STICS is a generic crop model that simulates the effect of climate, soil and crop management on yield and on environmental issues (e.g. Brisson et al., 2008). It was initially devoted to sole crops modelling (STICS-SC) but was also adapted to intercrops (STICS-IC) including two species in alternate rows (Brisson et al., 2004). This development was done in accordance with recent global change and environmental issues as intercropping could be one strategy to solve some problems linked to modern intensive agriculture (Brooker et al., 2015). One of the concepts behind this agricultural transition is that species coexistence in a same field could improve the resource use efficiency via the processes of niche complementarity and facilitation. It was illustrated in few studies, particularly in cereal-legume intercrops in low fertilization conditions (e.g. Bedoussac et al., 2015; Hauggaard-Nielsen et al., 2009). However, intercropping modelling requires considering ecological processes that are not usually included in crop models. The STICS-IC model was already used for simulating different intercrops in various European conditions and analyse in silico their performances (Launay et al., 2009; Shili-Touzi at al., 2010). The goal of this paper is to give a brief overview of the formalisms especially developed in STICS-IC to take into account species interactions for various types of intercrops, and to provide some trails in order to improve the formalisms.

Formalisms and limits in STICS-IC

By an extrapolation of a sole crop model, STICS-IC relies on the crop division into two parts: the dominant (higher) species and the understorey (smaller) one. Light resource is then partitioned between the two species using an energy balance taking into account the dominance of the two species for distributing the direct and diffuse light and its interception by the two species, with a possible species dominance inversion during the crop season (Brisson et al., 2004). Light amount, coupled with a resistive scheme taking into account evapotranspiration processes, allows to estimate the water requirements of each species. The nitrogen acquisition is also simulated dynamically according to each crop demand and the soil offer which is determined by the root density and depth of each species. For cereal-legume intercrops, the model is able to simulate niche complementarity for nitrogen resource thanks to the simulation of N_2 fixation of legume and the effect of soil nitrate content on N_2 fixation rate;

consequently if the cereal grows and uptakes faster available soil mineral-N, the legume N_2 fixation is boosted due to a lower inhibition of biological fixation by nitrate content.

Therefore, in a certain way, STICS-IC includes resource partitioning between the two coexisting species. Nevertheless, it has been shown that even if STICS-IC is quite satisfactory to simulate intercrop growth, few points need to be improved (Corre-Hellou et al., 2009; Launay et al., 2009). In particular, simulation of canopy height, from which depends light competition, should receive a particular attention. Moreover, there is no horizontal heterogeneity in the soil whereas some species particularly competitive for soil resources are able to colonize soil zones already occupied by another species. We analysed the formalisms of STICS-IC using published data on durum wheat-winter pea intercrops (Bedoussac et Justes, 2010) in order to identify which concepts and equations developed in the model should be changed in order to improve the simulation without strong modifications. Our results indicate that the model could be efficient for some intercrop designs (e.g. in alternate rows) but a more detailed modelling approach, spatially distributed, is required for other sowing designs.

Finally, depending on the limiting resource and the plant strategy (resource conservation versus acquisition), the different species are able to adapt differently. For example, if water is the main limiting factor, some species can increase carbon allocation to roots comparatively to aerial parts in order to counterbalance this lack. These kinds of ecological adaptations and processes should be included in an intercropping model. Therefore, the question directly deriving from this remark is: can they be integrated in a non-spatialized model such as STICS-IC or should we bring to the model the spatial heterogeneity using for example a spatialized discretization in the model?

References

Bedoussac, L., E.-P. Journet, H. Hauggaard-Nielsen et al. (2015). Agronomy for Sustainable Development, 35: 911-935.

Bedoussac, L., E. Justes (2010).Plant Soil, 330: 19-35.

Brisson, N., M. Launay, B. Mary, N. Beaudoin (2008). Editions Quae, Versailles, 300 pp.

Brisson, N., F. Bussiere, H. Ozier-Lafontaine et al. (2004). Agronomie, 24: 409-421.

Brooker, R.W., A.E. Bennett, W.-F. Cong et al. (2015). New Phytologist, 206: 107-117.

Corre-Hellou, G., M. Faure, M. Launay et al. (2009). Field Crops Research, 113: 72-81.

Hauggaard-Nielsen, H., M. Gooding, P. Ambus et al. (2009). Nutrient Cycling in Agroecosystems, 85: 141-155.

Launay, M., N. Brisson, S. Satger et al. (2009). European Journal of Agronomy, 31: 85-98.

Shili-Touzi, I., S. De Tourdonnet, M. Launay, T. Dore (2010). Fields Crops Research, 116: 218-229.