# Performance of the soil-crop model STICS for a wide variety of agronomic and environmental outputs under Belgian pedoclimatic conditions

**Keywords:** Crop model; STICS; Carbon balance; Multi-criteria evaluation

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The 2030 Agenda for Sustainable Development recognizes that food and agriculture lie at the very heart of the Sustainable Development Goals and that it is key to examine food systems in a global way when looking for the end of poverty and hunger altogether with responding to climate change. Such a research for food security and agricultural sustainability requires that, when analyzing and comparing farming systems or crop rotations, multidimensional indicators should be used, assessing both their productivity (quantitatively and qualitatively) and environmental impact (N leaching, GHG emissions, etc.).

In the present study, we evaluate the ability of the soil-crop model STICS (Brisson, 2003) to predict indicators related to agronomic (Leaf Area Index, dry matter, yield, N in the plant and in the grain, evapotranspiration) and environmental aspects (Soil Organic Carbon, soil nitrogen and water content, Net Ecosystem Exchange, Gross Primary Productivity, Ecosystem Respiration). STICS is a process-based soil-crop model that simulates crop growth as well as soil water, C and N balances. It takes as inputs weather, soil data and crop and management practices, and gives as outputs both agronomic and environmental variables. The 16-year (2004-2019) iCOS-LTO data (Lonzee Terrestrial Observatory, Belgium) were used. Crops have been cultivated following a 4-year sequence: sugar beet (SB), winter wheat (WW), potato (SP) and WW again. Mustard (MT) was planted as over crop prior to spring crops. The iCOS-LTO dataset is characterized by an important amount of available agronomic measurements and a daily acquisition of $CO_2$ exchange..

In this study, no parameter optimization process was applied. The standard plant files provided in STICS v9.2 were used for MT and SB. WW and SP had been calibrated in other studies (Dumont et al., 2014; Launay, 2022). Hydraulic properties of the soil file were derived using pedotransfer functions of the R package *euptf2* (Szabó et al., 2021) while the bulk density was computed using Bernoux (1998) pedotransfer equation.

Since STICS only simulates heterotrophic respiration and has, to our knowledge, never been used to assess complete carbon balance, rules were derived to compute GPP and NEE. Above-ground maintenance autotrophic respiration was computed from biomass and plant N content, following Sun et al. (2007). From there, different coefficients were applied to consider the below-ground maintenance autotrophic respiration (MR). Net photosynthesis (GPP) was derived from biomass C content increments. Finally, GPP and MR were used to compute Total Ecosystem Respiration following equations of Vuichard et al. (2016).

Results specific to the different indicators are contrasted. Total biomass, yields, evapotranspiration, NEE, GPP and RECO predictions range from very good (rRMSE < 0.5) to satisfactory (rRMSE < 0.7). It has to be noted that it remains not so easy to obtain satisfactory RMSE on large datasets. Other simulated indicators (SOC, SWC, LAI and N in the plant) were not satisfactory in terms of RMSE and would benefit from calibration.

This study is the first evaluation of STICS soil-crop model considering altogether such a large panel of indicators, including C balance and $CO_2$ emissions . It shows that STICS is adequate to evaluate multi-criteria performance of cropping systems. The innovative methodology proposed to simulate carbon

balance yielded very good results. The accuracy of STICS in predicting all indicators at once, concerning both agronomic and environmental performances, was demonstrated. More globally, it emphasizes the potential to use crop models to support the design of innovative cropping systems, allowing for a broader and finer comparison of crop rotations and management practices and accounting for their ability to mitigate and adapt to climate change.

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