Estimating CO_2 fluxes (GPP, RECO, NEE) of diversified crop rotations from STICS outputs

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Summary

CO_2 emissions constitute 75% of global net anthropogenic emissions (IPCC, 2013), inducing climate change. To study its impacts on cropping systems, modelling studies are primordial, enabling to investigate changing pedoclimatic conditions and to prospect potential farming systems with innovative management. But it is primordial that crop models, when evaluating climate change impacts, consider the interactions between soil organic carbon and carbon dioxide (Basso et al., 2018) not only at the level of a single crop but also for whole crop rotations.

With this goal in mind, we used the outputs of STICS in its standard pre-parameterized version to model the Gross Primary Productivity (GPP), the Ecosystem Respiration (RECO) and the Net Ecosystem Exchange (NEE). We based on the 16-year crop rotation of the ICOS BE-LON site (Belgium), which comprises five different crops (winter wheat, sugarbeet, maize, potato, cover crop), to calibrate and validate our methodology.

GPP is derived from the autotrophic respiration and from the Net Primary Productivity, which is calculated through the daily change in plant carbon (C) pools. The autotrophic respiration (AR) is computed from the plant biomass, the plant nitrogen concentration and GPP. The heterotrophic respiration (HR) was already an output of the STICS model, derived from the mineralization of residues and organic matter. Finally, RECO is the sum of AR and HR and NEE the sum of RECO and GPP.

The comparison of the simulations with the CO_2 fluxes measured on the BE-LON site indicated that the model is able to simulate accurately daily CO_2 fluxes (efficiency EF equal to 0.79 for GPP, 0.59 for RECO and 0.67 for NEE). Concerning the cumulated fluxes of the whole 16-year crop rotation, it appeared that the model evaluates this carbon budget accurately for RECO, with a slight underestimation (normalized deviation ND = 15.7%), and very accurately for GPP (ND = 5.12%). But for NEE, the relative overestimation induced by the model is higher (ND = 62.2%). This indicates that a more precise estimation of HR, whose computation is directly made by the STICS model, is required to obtain reliable net C budgets. This also suggests that the model, coupled with our external methodology, is for the moment more appropriate to establish comparisons between contrasted farming systems under various agro-pedoclimatic conditions rather than to provide absolute carbon budgets. We also discussed the influence of different environmental drivers on crop rotations CO_2 fluxes, and the model showed to be able to reproduce the trends observed with the field measurements.

Our generic methodology is easily transferable to any soil-crop model and proved to be a valuable tool to investigate the CO_2 exchanges of various crop rotations in historical and future climatic conditions.

References

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