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BOOK OF ABSTRACTS

Modeling agroecological intensification in the tropics with the Stics model – lessons learned and way forward

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The year 2023 will likely be the hottest ever recorded on our planet. Adapting to climate change and climate extremes is increasingly becoming a day-to-day concern for African farmers, along with food security and income issues. Agricultural adaptations like varietal choice and fertilizer doses have deserved great attention from the crop modeling community, and are overall well accounted for by crop models. Agroecological practices, for example residue mulching, rotation and intercropping with legumes and application of organic amendments offer great potential to adapt to climate change. Yet, they have deserved less attention when it comes to the modeling of their performance in tropical context. In this abstract, we describe a collective research effort to update and test the Stics soil-crop model to account for the impact of agroecological practices on cropping system performance in the tropics. We built on multiple years of measurements in contrasting experimental sites from cool to warm, semi-arid to sub-humid subtropical environments, in Senegal, Zimbabwe, Mali, Burkina Faso, Kenya, Brazil and Madagascar. We assessed the skills and pitfalls of the model to simulate i) new cereal and legume crops ii) cereal-legume intercropping, iii) crop residue decomposition and feedbacks on crop growth and iv) crop residue mulching.

We calibrated a new set of parameters for tropical maize (Falconnier et al., 2020), sorghum (Traoré et al., 2022, Ganeme et al., in revision), millet (Sow et al., forthcoming), rice (Ranaivoson et al., 2022), and legumes like cowpea (Traoré et al., 2022, Ganeme et al., in revision) and groundnut (Civil, 2022). Model accuracy (rRMSE) for end-of-season variables like aboveground biomass and grain yield was in the range of 20 to 50%. The scrutiny of in-season soil water and plant leaf area index (LAI) indicated that water stress was often underestimated, possibly because of underestimation of soil evaporation, and underestimation of the impact of water stress on LAI. Cereal yield with no fertilizer input was also not well reproduced, because of inadequate simulation of the soil organic matter mineralization that provides the mineral N required for plant growth. We are now working on implementing a new evaporation function into the model (i.e. new Stics modeling branch, Diop et al., this conference) to account for the specificities of warm tropical environments (i.e. the topsoil does not necessarily reach field capacity after a rainfall event). Our objective is also to implement a new mineralization function that is specific to the tropical context and allows for a better simulation of in-season soil organic matter mineralization. For legumes in particular, new data on nitrogen fixation will be used to test the accuracy of model simulation with the current set of calibrated plant parameters.

We assessed STICS ability to reproduce the performance of cereal-legume intercropping. STICS simulated the observed loss in legume yield due to competition for light with the taller cereal (Traoré et al., 2022). Competition for water (in relation to root growth) and nitrogen (in relation to N fixation of the legume) is being investigated with new observations currently processed. The impact of intercrops' relative densities, sowing date, fertilization, and the interaction with climate on intercropping performance and stability, is being investigated through sensitivity analysis (Traoré et al., in revision, de Freitas et al., this conference, Ganeme et al., in revision).

We evaluated STICS skills in reproducing the decomposition of organic amendment and the feedbacks on crop growth through provision of mineral N. We found that parameterizing the C/N ratio of legumes and keeping the default value of other decomposition parameters was sufficient to simulate accurately legume residues decomposition and N provision to the subsequent rice crop (Ranaivoson et al., 2022). We also found that STICS reproduced well the observed feedbacks between declining soil organic carbon and declining yield. In comparison, these feedbacks were not reproduced by all 16 soil crop models tested in a study of the AgMIP low input systems group (Couëdel et al, in revision). The impact of clay and pH on soil organic matter mineralization, as currently implemented in the model, leads to inaccurate long-term changes in soil organic carbon. Other parameters related to organic amendment decomposition need to be recalibrated in order to accurately simulate the impact of the incorporation of these residues on changes in soil organic carbon. As a way forward, we advocate for the need to develop a new mineralization function to better account for long term soil organic carbon changes.

Crop residue mulching helps reduce evaporation and can be a key adaptation strategy. Earlier simulation study showed that soil temperature under mulch (Balde, 2011) was not adequately represented, leading to poor simulation of soil organic matter mineralization. This issue is currently being investigated with new data collected in sub-humid Zimbabwe so that new formalisms can be implemented into the model (new Stics modelling branch, Diop et al., this conference).

This on-going work to assess and update Stics to a range of agroecological practices is very much open to new collaboration – please come and join us! This initiative is critical as it will improve our ability to design and test the much-needed adaptation strategies for smallholder farmers of the tropics.

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