sticRs: the R package for STICS users and developers

10 September 2019

Summary

Crop models are often written in programming languages with relatively low-level of abstraction such as `FORTRAN` or `C` because they are well-suited for scientific calculation. However, higher-level tasks such as programmatic model parameterization, data manipulation (*e.g.* import/export of measurements and model outputs, statistics, plots), distributed computation, model evaluation or sensitivity analyses are often not integrated into the model, but rather made as an independent, external process. The ease of use and reproducibility of these steps depends strongly on the ability to program them (Piccolo and Frampton 2016). Hence, developers tend to design modelling environments for that purpose using different tools such as java applications, Python modules or R packages.

The STICS model (Brisson et al. 2008) is a dynamic, generic and robust model to simulate the soil-crop-atmosphere system. It has been developed for more than twenty years (Brisson et al. 1998) by more than 50 authors, and is now used by hundreds of users (1100 downloads as of 2012) across academic field (*e.g.* INRA, CIRAD, IRSTEA, more than 230 international papers), government agencies and technical institutions (Arvalis, French chamber of agriculture), international projects (H2020 ReMIX, agMIP), and schools (SupAgro). Hence, developing a complex model with as many users implies a thorough and careful development, while remaining easy to parameterize and use.

Excluding meteorological data, the STICS model needs more than 300 parameters for sole crops. These parameters are not always easily measurable on the field, measured with high variability, or simply not readily available to the user (Tremblay and Wallach 2004; Launay and Guerif 2005). Hence, a user should always evaluate the model sensitivity to the parameters before setting an approximated value (Varella, Guérif, and Buis 2010). The model has also different options for some formalisms (*e.g.* light interception), and the user should evaluate which is better suited for his particular use case by comparing the model outputs.

A developer that modifies a new formalism or designing a new one should also evaluate its impacts on the model outputs, and make a systematic comparison between different model versions or parameterization along field observations.

Therefore, STICS users and developers often experience the same different steps in their journey:

- Read, write or add parameters and their values
- Test the model programmatically for different parameter values, formalisms or model versions
- Evaluate the model against field observations
- Make plots
- Make a sensitivity analysis
- Optimize the parameter values using observations
- Distribute the runs across multiple cores / machines

`sticRs` is an R package that was designed to make these steps as easy and fast as possible, and more importantly, reproducible. It has been adapted for the regular sole crop version of STICS, but also to its intercrop version (Corre-Hellou et al. 2009). The following diagram presents a typical workflow using the main functions from `sticRs`:

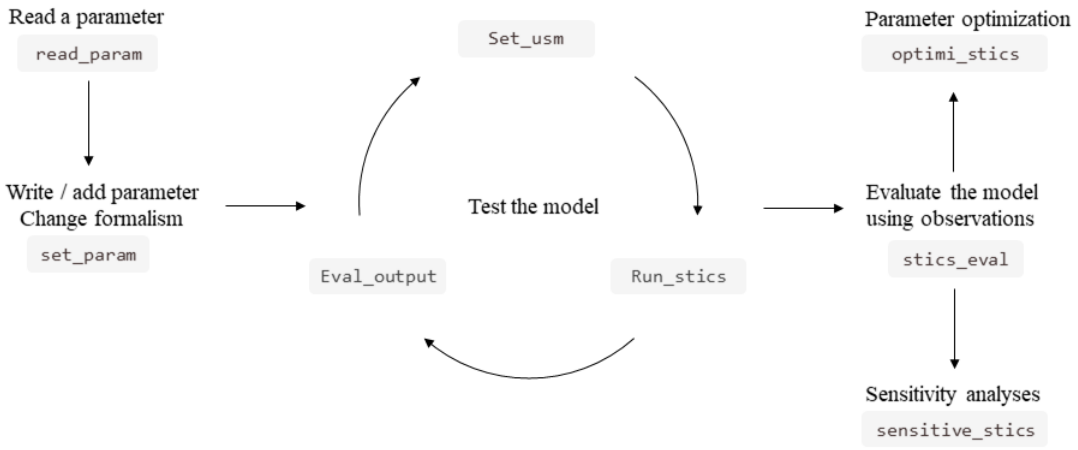

Figure 1: sticRs workflow

Evaluating the model is so fast and straightforward using `sticRs` that this step is often bypassed by the user to directly make a model evaluation using the `stics_eval` function, which is a wrapper of the previous functions. The package also automatically distributes the simulations across computer cores when the user call `stics_eval` and `sensitive_stics`.

`sticRs` documentation is accessible on its dedicated website (https://vezy.github.io/sticRs) along with three tutorials:

1. Get started;
2. Sensitivity analyses;
3. Parameter value optimization.

The source code of the package has been archived to Zenodo with a concept (*i.e.* permanent) DOI (Vezy 2019).

Acknowledgements

The authors acknowledge the financial support from the European H2020 funded ReMIX project (https://www.remix-intercrops.eu).

References

Brisson, Nadine, Bruno Mary, Dominique Ripoche, Marie Hélène Jeuffroy, Françoise Ruget, Bernard Nicoullaud, Philippe Gate, et al. 1998. "STICS: A Generic Model for the Simulation of Crops and Their Water and Nitrogen Balances. I. Theory and Parameterization Applied to Wheat and Corn." *Agronomie* 18 (5-6): 311–46.

Brisson, N., Launay M., B. Mary, and N. Beaudoin. 2008. *Conceptual Basis, Formalisations and Parameterization of the Stics Crop Model*. Quae.

Corre-Hellou, Guénaëlle, Marieline Faure, Marie Launay, Nadine Brisson, and Yves Crozat. 2009. "Adaptation of the Stics Intercrop Model to Simulate Crop Growth and N Accumulation in Pea–Barley Intercrops." *Field Crops Research* 113 (1): 72–81. https://doi.org/https://doi.org/10.1016/j.fcr.2009.04.007.

Launay, Marie, and Martine Guerif. 2005. "Assimilating Remote Sensing Data into a Crop Model to Improve Predictive Performance for Spatial Applications." *Agriculture, Ecosystems & Environment* 111 (1-4): 321–39.

Piccolo, Stephen R., and Michael B. Frampton. 2016. "Tools and Techniques for Computational Reproducibility." *GigaScience* 5 (1): 30. https://doi.org/10.1186/s13742-016-0135-4.

Tremblay, Marie, and Daniel Wallach. 2004. "Comparison of Parameter Estimation Methods for Crop Models." *Agronomie* 24 (6-7): 351–65.

Varella, Hubert, Martine Guérif, and Samuel Buis. 2010. "Global Sensitivity Analysis Measures the Quality of Parameter Estimation: The Case of Soil Parameters and a Crop Model." *Environmental Modelling & Software* 25 (3): 310–19. https://doi.org/https://doi.org/10.1016/j.envsoft.2009.09.012.

Vezy, Rémi. 2019. "VEZY/sticRs," May. https://doi.org/10.5281/zenodo.1344555.