Preface

Francois F. Tardieu

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What is a crop model? 'Snake oil' (Passioura 1996), i.e. an impossible (and moderately honest) challenge to fit the current scientific knowledge into a single framework? A mechanistic view of plant growth and development which represent causality between component processes and yield (Yin et al. 2004)? Robust empirical relations between plant behaviour and the main environmental variables (Passioura 1996)? A tool for analysing plant behaviour and its genetic variability which bypasses, but may help to increase the knowledge about underlying mechanisms (Tardieu 2003, Hammer 2006)? All these definitions are partly true, all are potentially misleading.

Considering the achievements of crop models is perhaps the best way to understand what they are. STICS and other crop models have profoundly changed the vision that the agronomic community had of the soil – plant – atmosphere system and of its interactions with cultivation techniques. It has also changed the way agronomists design experiments and test hypotheses. Important and legitimate questions such as "which is the best sowing density for a crop?", "is an early cultivar better than a late one?", "what is the best fertilisation strategy?" have been the subject of hundreds of experiments in the 60's and 70's. Nobody would now imagine answering them without a model because "try it and see" experiments may well be the worst method for answering them, due to experimental errors and to the variability of behaviour of each genotype in different environments. Although our current knowledge is often poor for detailed processes, the behaviour of soil-plant-atmosphere systems is surprisingly predictable in relation to what could be expected from the synthesis of all mechanisms involved in it (Tardieu 2003). STICS, like other crop models, can therefore help to answer the above questions for a wide range of conditions which could never be tested experimentally. The role of experiments has changed, and is now to check whether experimental results, obtained in a limited number of environmental conditions, are consistent with those of the model in a wide range of situations to verify the credibility of the model in the studied range of environments (Lyon et al. 2003, Corre Hellou et al. 2007). Lack of agreement between the model and the experiments may suggest ways for improving some aspects of the model.

Is this science or engineering (Passioura, 1996)? This lengthy debate has been largely fruitless. The same model can be used for good or unexciting science, for good or inappropriate engineering. The important point is that the user is able to be critical with the model, so that his/her judgement or decisions after using STICS will be the result of some personal input and understanding of the model. This is the objective, hopefully fulfilled, of this book.

Making it clear, that STICS is a tool for reasoning and not a magic wand for prediction, is one of the main aims of this book. The model is by no means an exact representation of all the processes involved in a virtual experiment. It is therefore essential that the user has access to its workings, i.e. its architecture, equations and parameters, and that the robustness of equations is discussed and compared with that of other models. The reader can find every single process used in the STICS model, with its equations and parameters, and with figures which explain the meaning of equations and their consequences on model outputs. This gives several possibilities to the user. Most skilled users can go into the detail of some processes, check the consistency of hypotheses with their own ideas, and interpret results according to this information ("I get this output with that hypothesis, would I get a different output with this other hypothesis? "). Less skilled users will use the book for understanding the reasoning which accompanies the equations of a particular module. For instance the observations of Figure 5.2 and 5.3 clearly suggest that the objective is not to compare the root systems of rape seed, corn and wheat, which vary widely between fields, but to investigate what happens if the characteristics of the root system change with the species or with the soil ("examples are given for 3 species. What would be the behaviour of my favourite species in my soil?").

STICS is based on simple processes, essentially the same as in other crop models, but with some appreciable differences in method. This book clearly presents the basis for computing the progression of phenological stages from temperature, the light interception by leaves following Monteith's equation, the transpiration following Penman Monteith's equation, and the water and nutrient uptakes following Gardner's pioneering work. To my knowledge, these fundamentals do not differ essentially from those of other models (Yin and Van Laar 2005, Keating et al. 2003) except that the equations used in STICS have been chosen in a more "physics-oriented" way than those of other models. In STICS, as in any other model, things become less straightforward for simulations of growth and of distribution of assimilates and responses to environmental stresses. The STICS group was successful in representing complex networks of interactions without generating scores of equations and parameters which can never be checked. Are the methods used in STICS better than those of other models? Another book could be written to compare the respective value of the algorithms used in different models. For most users, it is enough to know that methods and algorithms are coarse but useful representations of reality and that they can vary substantially between models, so it may be useful for some purposes to compare the output of STICS with those of other models.

An important side effect of the work of the STICS group has been to provide a common "meeting place" for scientists of several agronomic disciplines (plant science, soil science and cropping systems), for social scientists and for people working in extension services. This book should help to provide a bridge between scientific communities. It is a necessary tool for scientists who use the STICS model, for agronomists who are curious about the different topics which can be covered with crop models, and for modellers of different disciplines who wish to copy the methods of the STICS group. Will geneticists and molecular physiologists join the community of plant modellers? This is a major challenge for the years to come. Progress has been made (Hammer et al. 2006, Struik et al. 2007, Chenu et al. 2008), but these two groups seem reluctant to employ modelling methods (see e.g. Benfey and Mitchell-Olds 2008).

In conclusion, we have to be grateful to the authors, especially Nadine Brisson, for carrying out the huge and difficult task of explaining the detail of all that is involved in the STICS model.

François Tardieu

François Tardieu is a crop scientist and an ecophysiologist who works to fill the gap between agronomy and genetics. He was involved in projects in which crop modelling had an essential role. This, together with his role in scientific management in Inra (France) gives him a wide overview of the uses and concerns of crop modelling.

The STICS crop model has been developed since 1996 at INRA (French National Institute for Agronomic Research) in collaboration with other research and technical institutes.

The model syntheses, illustrates and concretizes an important part of the French agronomic knowledge as a point of view on the field and cropping systems working. The formalisations of the STICS crop model presented in this book can be considered as references used in the framework of crop sciences. They will help professionals and students in the partitioning and understanding of the complex agronomic system. The book arrangement relies on the way the model designs the crop-soil system functioning, each chapter being devoted to a set of important functions such as growth initiation, yield onset, water uptake, transformation of organic matter etc. One chapter deals with the cropping system and long term simulations and the final chapter is about the involvement of the user in terms of option choices and parameterization.

If this book is mainly intended for scientists who use the STICS model, it can also be useful for agronomists, crop modellers, students and technicians looking for elementary formalizations of the crop-soil system functioning.

Nadine Brisson is a crop scientist, working at INRA. She is at the origin of STICS and has a large experience in crop modelling built, for twenty years, from various approaches, issues and crops. She is involved in programs where the model is used in various ways as a heuristic, prospective or experimental tool. She is head of the INRA agroclimatic service.

Marie Launay is a crop scientist, working at INRA. She is responsible for STICS agrophysiology and is particularly involved in STICS adaptation to new crops. She is in charge of training and communication about the model. She is now at the head of the research project on biotic stress formalizations into the crop model.

Bruno Mary is a senior scientist, working at INRA. He developed the STICS modules devoted to the crop and soil nitrogen balance. For almost thirty years, he has been studying soil C and N cycles by associating experimental and modelling approaches, either with mechanistic or functional models. He collaborates in several programs concerning C and N storage, N gaseous emissions and N mineralization, in various agro-ecosystems.

Nicolas Beaudoin is an agronomist, working at INRA as research engineer. He contributed to the soil module conception and parameterisation. He uses STICS for predicting nitrate leaching and crop yield at several spatial scales and for studying the long term nitrogen balance of various cropping systems, including crop devoted to energy production.

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