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Book review

Agricultural system models in field research and technology transfer
Edited by L.R. Ahuja, L. Ma, T.A. Howell

This volume is a collection of 16 expository review chapters, each on some aspect of crop modeling. Although not necessarily evident from the title, the book is almost exclusively devoted to crop simulation models: there is one chapter on forage models and virtually no mention outside of this chapter of animal physiological or behavior models. To quote from the first sentence of the Preface, the purpose of the book is "to present the state-of-science of applications of agricultural system models, and tremendous benefits to be derived from the use of these computer models in agriculture research and technology transfer in the 21st century." The editors are all USDA-ARS scientists, and the Foreword, written by an ARS administrator, implies that the project of developing the book was conceived within that organization.

The editors have clearly made some effort to include a perspective from outside the USDA. Of the 16 chapters, five have no authors from either ARS or the ARS-associated IBSNAT modeling program. Two of these, however, represent the experience of users of models developed by USDA-ARS scientists, so that there are only three papers that have little or no ARS influence. Two are from the CSIRO modeling group in Australia, and one is from the group at the Center for Agricultural Landscape Research in Muencheberg, Germany. In part, this reflects the dominant role that ARS scientists have played over the last three decades in the development of successful crop models, that is, crop models that are useful and survive to be used by people outside the lab where the model was developed. There are, however, some notable absences. The scope of the book would have been much enhanced by the inclusion of chapters from the Wageningen school, as well as from the group associated with James Thornley, to name two examples. The primary focus of the volume is on models developed under the auspices of ARS (primarily EPIC, the CERES and CROPGRO models, and GOSSYM and GLYCIM). A good source of further information for those unfamiliar with crop model acronyms is the Register of Ecological Models, http://eco.wiz.uni-kassel.de/ecobas.html

After the introductory overview chapter written by the editors the remaining chapters are organized into a sequence of four thematic groups. The first group, Chapters 2 through 5, represent what may be loosely described as the developers' perspective. These chapters describe the history and philosophy of the programs that produced FARMSCAPE, GOSSYM/COMAX, GLYSIM, and the DSSAT collection, which incorporates the CERES and CROPGO models. In each of these chapters the focus is not so much on the internal workings of the models as on the history of their development, the goals of the modelers, and how the model achieved

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these goals. None of the chapters contain a detailed description of how the model works; there are few flowcharts and virtually no equations. In each chapter there are a number of fairly detailed descriptions of successful applications of the model, both in research and in support of farm management or policy decisions.

Chapters 6 through 9 represent what might be considered the user perspective of these models. Chapter 6, written by scientists from the International Fertilizer Development Center, describes their experiences with models in various applications, both at the farm and the policy level, in Asia and Africa. Most of the discussion involves the DSSAT models but there is also some discussion of other models such as QUEFTS and COTONS. Chapter 7 provides a systematic and thorough comparison of the RZWQM, CROPGRO, and CERES-Maize models under a variety of applications. Chapter 8 describes the experiences of the authors in implementing models for decision support in Australia. Both this chapter and Chapter 6 detail some of the problems experienced in using models as on-farm decision support tools. This is a sufficiently important topic that I will devote a more lengthy discussion to it later in the review. Chapter 9 reviews a variety of models to a variety of applications in semi-arid regions.

Chapters 10 through 13 are devoted to the currently most active area of crop modeling research: the incorporation of spatial variability into simulation models through linkage with a geographic information system. Hartkamp et al. (1999) provides a review of this topic that contains a very useful structure for organizing and classifying the various ways to link a model with a GIS, and this paper is a good introduction to the subject before reading these chapters. As with single-plant crop simulation models such as those described in Chapters 2 through 5, some of the most prominent and successful farm and landscape scale models, such as ALMANAC and SWAT, have been developed under the auspices of USDA-ARS. Chapter 10 provides a description of these models and a demonstration of their use to various problems at different spatial scales. Chapter 11, which is one of two European contributions to the volume, describes the application of the HERMES simulation model to two questions involving spatially variable fertilizer application. Chapters 12 and 13 contain two relatively short discussions of linking a simulation model to a GIS to simulate spatial variability at the field level, and of the incorporation of topographic variability into a simulation, respectively.

Chapters 14 through 16 discuss various topics in crop simulation model research. Chapter 14 provides a systematic and useful review of the problem of parameter estimation and how to do it in a statistically consistent manner. Chapter 15 provides a description of the Object Modeling System (OMS) project currently under way at USDA-ARS. This is a laudable attempt to develop a common standard for object-oriented model development that, if implemented on a wide scale, would permit more efficient interchange of components of crop simulation models. Anyone who has ever waded through pages of FORTRAN code sprinkled with GO TO statements can only applaud this effort. Finally, Chapter 16 forecasts some future directions of research in crop simulation modeling.

The subtitle of the volume explicitly addresses the twin applications that have motivated the development of crop simulation models over the years, field research and technology transfer (which prominently includes decision support). Not surprisingly, the conclusions of most individual chapters are largely upbeat. The two principal exceptions are in Chapters 6 and 8, which mention some of the difficulties associated with the use of crop models in on-farm decision support. On a personal level, my own experiences probably reflect those of many who have been involved with crop modeling. On the one hand, crop simulation models can provide a useful tool for developing precisely stated hypotheses that are subject to test in field experimentation. On the other hand, the international effort to develop farm-level decision support systems (DSS's) based on crop models and expert systems (a form of model), which began in the late 1980's with such high expectations, had by the end of the century been largely abandoned as a failure. The authors of Chapter 8 have themselves sponsored a collection of papers published in the journal *Agricultural Systems* that addresses the roots of this failure. In the introductory paper to this collection, McCown and Carberry (2002) develop a subtle and well-thought out analysis. At the risk of oversimplifying their work, I want to focus on one aspect of it.

McCown and Carberry (2002) note that the failure of DSS in agriculture reflects a more widespread failure of such systems observed throughout the discipline of operations research. One of their ascribed causes of this failure is the "Delphic" approach to DSS in which the flow of information is strictly in one direction: from the system to the user. Technology transfer workers in Australia have responded by developing a new paradigm, described in Chapter 8of the reviewed volume, in which farmers and scientists participate in group exchanges of information, with the simulation model serving as a vehicle for enhancing discussion and understanding. This experience reflects my own and that of other researchers and I think may be generalized to other applications of simulation modeling.

In their insightful history of crop simulation Sinclair and Seligman (1996) make the case that those who benefit most from the development of a simulation model are the modelers themselves, through the use of the development effort as a vehicle for organizing one's thoughts and synthesizing linkages between knowledge segments. (This paper is part of another special series of papers, entitled "Use and Abuse of Crop Simulation Models," that should also be on the reading list of anyone interested in this subject.) Sinclair and Seligman present an unpublished argument of Imanuel Noy-Meyer that states that it is not necessary even to complete the development of an actual model to achieve the benefit. While this takes the argument perhaps to an extreme point, the combined experiences presented here indicate that successful use of a crop simulation model as a technology transfer tool requires a collaborative effort between farmers and scientists in which the model is used as a device to assist in organizing knowledge of the participants, rather than as a source of knowledge in itself. Similarly, a model can be best used as a research tool if individuals who understand its assumptions and limitations use it to propose experiments whose outcome can be interpreted within these limitations to test a well-formed hypothesis.

So where does that leave the subject of this book review? Obviously, all of us who have worked with models and decision support systems over the last 20 years or so have emerged with a few lessons learned, sometimes the hard way. With the exceptions already noted, the volume does not really offer much in the way of lessons learned through failure, and thus perhaps presents an overly optimistic view of the potential of crop models as research and decision support tools. There have been many successes, however, and crop models clearly have a significant place in the scientific toolbox, both in research and in technology transfer. Those who want to learn about crop modeling and are seeking an objective comparison of a wide variety of crop models developed around the world will likely be disappointed by this volume. Those who are seeking information on the many prominent crop simulation models developed under the auspices of, or in collaboration with, the USDA-ARS, and examples of highly successful applications of these models, are likely to find exactly what they are looking for. It is a tribute to the prominent role of the ARS in crop simulation modeling that there are sure to be a very large number of scientists who fall into this second category.

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