Review of Soil Physics with Python

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Book Reviews

Review of *Soil Physics with Python: Transport in the Soil–Plant–Atmosphere*

Marco Bittelli, Gaylon S. Campbell, and Fausto Tomei. Oxford University Press, 2015. 449 pp. ISBN-13: 978-0199683093. $98.50.

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At the time Gaylon Campbell published *Soil physics with BASIC*, in 1985, the soil physics community in the United States was still divided on whether the teaching of soil physics should necessarily require that students be able to manipulate mathematical, let alone arithmetic, equations. Some lecturers were proud of the fact that their soil physics courses did not involve a single equation! Also, in 1985, personal computers were still a curiosity, and only a few privileged researchers had one equipped with a hard drive. Needless to say, in this context, *Soil Physics with BASIC* caused quite a stir, not only because it made no apology for considering mathematics as the essential language of physics, but especially because it conveyed unequivocally the message that it was crucial for soil physics students to know first hand how to program computers.

The intellectual landscape has changed appreciably since 1985. This new, heavily and expertly revised edition of Gaylon Campbell's book, co-authored with Marco Bittelli and Fausto Tomei, is being made available to a soil physics community that is now overwhelmingly convinced of the intrinsic worth of using mathematics. The notion that the ever-increasing power of computers is essential to resolve difficult problems and predict soil behavior is also a no-brainer in the discipline. Nevertheless, the authors still run against the tide in one significant respect. A common sales pitch associated with software packages used today in soil physics is that they have reached such a level of versatility, reliability, and user-friendliness that they can be used easily without any knowledge of programming whatsoever. Bittelli, Campbell, and Tomei clearly do not share this opinion but are convinced instead that soil physics students should write, debug, and run computer programs, as well as able to grasp line-by-line what any computer program is doing.

The book has been cleverly thought out in this respect, and it introduces readers to programming in a gradual way. Readers are not assumed to have a large amount of experience with computer programming. A well-conceived 28-page-long appendix does a very good job of introducing the basics of programming in general and of the Python language more specifically. Any reader with the patience to go through this appendix could rapidly get up to speed. The authors have also smartly ensured that the first few programs presented in the text are short and structurally simple, which should give the impression to readers that programming is not too difficult an art to master. The complexity of programs increases progressively in the book, so that by the end, readers are fully equipped to tackle programs of just about any size. In this context, the authors' choice of Python makes eminent sense for a number of reasons. Python programs are very portable. Even though it is a high-level, object-oriented language, Python is simple to learn, for example, relative to C++, which would have been the logical alternative. As with C++, many libraries exist that enable even the most complex scientific computing to be performed in Python. Because it is an interpreted language, Python tends to be slow, but the book describes ways (e.g., with Cython) to speed up computations significantly, should it prove necessary.

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This book is very likely to achieve its laudable objective of producing soil physicists who can "look under the hood" of computer programs (at least of the "free" software for which the source code is kindly made available), and who do not have to accept program outputs blindly. One side effect is that readers of this book may end up getting frustrated when using "non-free" or "non-open-source" software, whose hood remains irremediably shut, figuratively speaking. However, I personally cannot conceive of that frustration really as a shortcoming of the authors' approach. Quite the contrary, it would instead be a positive outcome for the soil physics community as a whole, which at this stage would benefit tremendously from totally free sharing of computational resources. The sooner we get there, the better.

A key question regarding this book is whether it is suitable, on its own, as an introduction to soil physics. In general terms, the answer is yes, since in its 449 pages, the text covers most aspects of the soil–plant–atmosphere continuum that are traditionally dealt with in other textbooks. Specifically, it deals with hydrostatics, gas diffusion, soil temperature and heat flow, water retention and transport in both saturated and unsaturated soils, solute transport, evaporation, transpiration and plant–water relations, and soil spatial heterogeneity (without rehashing once more the old kriging equations, which is nice). More or less all the usual topics are dealt with that one would think essential for an introductory course in soil physics. Only one chapter falls somewhat outside the range of what is typically covered in such a course. The authors have felt it appropriate to include a 40-page chapter on "triangulated irregular networks," which some instructors who are more focused on local applications of soil physics, such as in the context of agricultural field plots, may eventually skip. However, anyone who is keen to deal with water and solute transport processes at watershed and regional scales, and with the combination of soil physics models with geographical information systems will undoubtedly find the material in this chapter to be of great interest.

From a didactic perspective, the book manages to propose a refreshingly new take on some topics, for example when, in Chapter 2, it deals first with soil structure and leaves the coverage of the particle size distribution for the end of the chapter. The very detailed explanations accompanying each Python programs also are very useful. Inclusion of between two and eight exercises after individual chapters is also a plus. On the down side, compared to other textbooks, the presence of numerous computer programs decreases somewhat the space available to describe a number of standard topics in detail. For example, sections describing the different instruments used in practice to measure the soil water content, the different components of the soil water potential, or the (un)saturated hydraulic conductivity, are lacking. The text also does not provide cautionary notes that would have been welcome, for example, about the flaky concept of "field capacity", the theoretically unsound "osmotic" water potential, or unphysical predictions to which the "diffusivity" equation (or θ-based form of Richards' equation) may lead to under some circumstances.

These, and a few other similar omissions at various points in the text, mean that the book is not ideal for self education in soil physics, unless an altruistic soul decides to put together a "companion" booklet that provides some of the missing pieces. From a broad educational perspective, especially from the standpoint of practitioners who may otherwise have benefited greatly from the book, one may consider that this is a pity. Nevertheless, I am not convinced that this is a major drawback for college instructors who would consider using the book as assigned reading for a campus-based or online undergraduate or lower-level graduate course. All that would be needed would be for them to excerpt short sections from other soil physics textbooks, and assign them as complementary readings to make sure that students get a complete and accurate picture of the field.

Overall, I believe that the authors have rendered an extremely valuable service to the soil physics community with the publication of this nicely written and appealingly presented text, which I wholeheartedly recommend to soil physics students of all ages. I will definitely not hesitate to use it as a textbook in my own courses. If this great book were adopted widely, it would help train a new generation of soil physicists armed with a very solid understanding of what it *really* means to use computers to describe soil physical processes, and who would not be at the mercy of commercial software developers to satisfy their computational needs. At this stage, soil physics desperately needs such skilled people to move forward.