The characterization of soil-water-solute processes in the vadose zone is a major challenge in many disciplines, including the soil sciences, agricultural engineering, hydrology, geology, and soil remediation. Research in this area has progressed enormously in the last decade, especially with respect to novel measurement techniques but also in relation to the development and use of mathematical models caused by an apparently unlimited growth in computational power. Soil measurement technology and mathematical modeling of soil processes thus far have advanced both at their own pace and almost independently from one another. There is therefore a need to evaluate and reflect not only on measurement techniques presently available to characterize and monitor soil processes, but also on the use of this information to improve models and to predict the behavior of water and the fate of solutes and contaminants in the vadose zone. This book aims to fill this gap by providing scientists and practitioners with an integrated approach that will enable them to make appropriate choices in terms of available methods for characterizing soil-water-solute processes and models describing them.

The authors have organized their book into six sections, which cover three main parts. The first part, which is also the first section, defines the basis for an integrated approach of soil characterization. This section, which includes three chapters, sets the scene and provides a basis for the other two parts. The second part of the book deals with an extensive and critical evaluation of methods presently available to analyze and quantify energy and water transfer, chemical transport, and soil microbial processes. The third part covers the quantification of spatial and temporal variability in soil processes and transport modeling techniques. In the following, the three parts are discussed in more detail.

The first part contains three chapters. Chapter 1 presents a multidisciplinary approach for assessing subsurface nonpoint source (NPS) pollution. It proposes a six-stage methodology that can be followed to develop deterministic models for nonpoint-source pollution. The importance of scale and spatial variability in the parameterization process is discussed, including the role of GIS in upscaling model simulations. The role of spatial and temporal variations of soil processes in relation to studying soil-water-solute processes is the content of Chapter 2. This chapter provides the reader with a general discussion of the deterministic and stochasticity of soil processes and the issue of scale in the design of field studies. Chapter 3 provides a short overview of general concepts and the mathematical description of soil-water-solute processes.

The two remaining parts are covered in 18 chapters that are organized into five sections (2–6). Section 2 deals primarily with energy and water transfer in soils (Chapters 4–8). Chapter 4 deals with the major water balance terms like evaporation, interception, and recharge. Remote sensing methods for biophysical properties such as vegetation cover are also presented. Chapter 5 covers field methods for the soil water status such as time domain reflectometry (TDR), frequency domain reflectometry (FDR), tensiometers, heat dissipation sensors, and soil psychrometers. Evaluation criteria for volumetric soil water methods and soil tensiometric methods are given. Section 6 covers traditional methods such as ring infiltrometers, well or borehole infiltrometers, and tension or disc infiltrometers. The presentation of these methods is accompanied by a clear description of the underlying physical principles. Chapter 7 presents new technologies such as nuclear magnetic resonance imaging (NMRI) and X-ray tomography to study soil–plant–water processes. The chapter provides a clear description of the fundamental physical principles. Chapter 8, a brief introduction to the part of field processes and their mathematical formulation, is covered in this section.

Section 3 is devoted to chemical processes (Chapters 9–14). In Chapter 9, field methods for solute transport are discussed. Direct and indirect methods are presented such as geophysically based techniques like the resistivity method and electromagnetic induction, and emerging technologies such as fiber optics. Chapter 10 provides a detailed evaluation of the usefulness of TDR as a measurement technique for solute transport in soils. This chapter is logically followed by a chapter dealing with the analysis and interpretation of breakthrough curves obtained from typical columns in the laboratory. In addition to standard methods for analyzing breakthrough curves, this chapter introduces different experimental techniques for characterizing equilibrium solute transport in soils. The next chapter is a brief analysis of different methods available for sorption–desorption processes of pesticides in soils. In Chapter 13, measurement methods to determine soil-surface gas fluxes, such as chamber techniques and mass exchange methods using micrometeorological techniques, are presented. These methods nicely complement the theoretical material in Chapter 4. Finally, Techniques for the characterization and evaluation of microbial processes, nor does it allow for a comprehensive coverage of the various modeling approaches that can be used for this purpose.