SOILS: BASIC CONCEPTS AND FUTURE CHALLENGES

This book was born as an international tribute to Fiorenzo C. Ugolini, an outstanding soil scientist who recently retired from university teaching and research. It is a fully up-to-date synthesis of the present knowledge of soils, their genesis, functions and management. It includes contributions from leading soil scientists and the result is a book that provides the basic concepts as well as the latest data and practical examples from across the discipline, including many issues that are overlooked in other treatments. The book also discusses the increasingly important role of soils in enabling the preservation of life.

Soils: Basic Concepts and Future Challenges provides the necessary keys to name soils and soil horizons. It contains a rare attempt to cross-harmonize the Reference Soil Groups of the World Reference Base of Soil Resources with the Soil Orders of the Soil Taxonomy, and presents a novel analysis of the various soil-forming factors. The book also quantifies the global extent of human-impacted soils, and the possible existence of extraterrestrial soils based on the findings from the last space missions.

This volume will be a valuable resource for researchers and students of soil science, soil conservation, geography and landscape ecology.

The Editors of this book, Giacomo Certini and Riccardo Scalenghe, are researchers at the Universities of Florence and Palermo respectively. Authors of numerous papers in international journals dealing with soil science and ecology, they have carried out studies in various European countries including Italy, Norway, Poland, Spain, Switzerland and the UK. They teach topics related to soil, water and the environment.

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'We might say that the earth has the spirit of growth; that its flesh is the soil.'
Leonardo da Vinci

This book pays homage to Professor Fiorenzo C. Ugolini, who has recently retired from his long career as a university professor of soil science. All the authors of this book had spirited interactions with him. He is an enthusiastic and inspirational teacher and scientist, a tremendous mentor and friend, and a talented Renaissance man. We all benefited greatly from his valuable contributions through which he enriched us and our discipline, soil science. For this reason, and perhaps also for the vital energy Professor Ugolini showed on every occasion, the authors accepted with enthusiasm the invitation to contribute to this book dedicated to his career.

We hope that this text represents a useful resource for preparing future soil scientists.

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Preface

Soil is a dynamic natural body occurring in the upper few metres of the Earth's surface at the interface between the atmosphere, biosphere, hydrosphere and geosphere. A soil is both an ecosystem in itself, and a critical part of the larger terrestrial ecosystem. From the earliest perceptions of soils as the organic enriched surface layer to today's pedologic horizonation of profiles, there is a rich history of beliefs and understanding of this vital life-sustaining resource.

In Chapter 1 changes in perceptions of soils and their classification are explored. Chapter 2 describes some of the specific reactions that are components of the soil-forming processes that transform geologic materials into recognizable pedologic features and horizons. Solids, along with the liquids and gases that fill pore spaces between the solids, compose the three-phase soil system.

Chapter 3 treats the inorganic fraction of the solid phase, examining differences between primary minerals, derived directly from rocks, and secondary minerals, formed by pedogenic processes. Soil organic matter is discussed in Chapter 4. It is often a minor fraction of soil in quantitative terms, but exerts a major control on soil properties. Soil organic matter is complex, being a mixture of a multitude of different components. Organic matter may be tightly bound to clay surfaces by adsorption or physically protected by entrapment within aggregates. These associations modify the physicochemical and physical properties of the mineral phase and affect organic matter biodegradation rates.

The liquid phase of soil is an aqueous solution of solids and gases. It is dynamic and highly sensitive to changes occurring in the soil ecosystem. As shown in Chapter 5, studies examining soil solution chemistry can be a powerful approach to elucidate pedogenic processes, equilibrium and kinetic factors, solute transport, soil fertility, nutrient cycling, and the fate and transport of environmental contaminants. Chapter 6 provides an overview of the composition and dynamics of the soil gaseous phase. This phase has received considerable attention in recent years due to the realization that soils act as a global source,

sink and reservoir of gaseous substances that control the atmospheric composition and thus affect the global climate.

Soil biota, the biologically active powerhouse of soil, includes an incredible diversity of organisms. It has been reckoned that there may be greater than 4 trillion organisms per kilogram of soil and more than 10 000 different species in a single gram of soil! Chapter 7 examines how soil biota plays a tremendous role in a number of soil properties and processes.

Genetic soil science (pedology), espoused by Dokuchaev and colleagues in Russia in the late 1880s, described soils as independent natural bodies resulting essentially from interaction of five environmental factors: parent material, climate, topography, biota, and time. Chapter 8 outlines how Hans Jenny rigorously defined or redefined the meaning of these factors, and more importantly, added the new concept of the *soil system*, which when combined with these factors provides a powerful conceptual framework to study and understand soils.

The influence of parent material as a soil-forming factor is an inverse function of time, making it especially important in young soils. Chapter 9 focuses on the impact of dissimilar parent materials – granite and basalt, the two most widely occurring igneous rocks on the Earth's surface – on the physical and chemical properties of soils in the context of different weathering intensities.

Climate, often the predominant soil-forming factor when considering soil development over the long term, is treated in Chapter 10. Temperature and precipitation are the most important components of climate. Temperature strongly influences the rates of chemical and biological reactions while soil moisture contributes to the dissolution, neoformation and transport of materials. Climate also determines the type and productivity of vegetation that, in turn, affect soil formation.

Topography, referring to the configuration of the land's surface, can have a major control on soil genesis. Chapter 11 examines the influence of topography on the disposition of energy and matter experienced by soils on the landscape. Slope, aspect, elevation and position modify the regional climate, causing soils to intercept more or less water and solar energy. Fine-scale topographic features may also influence pedogenesis by trapping aeolian dust, altering water infiltration patterns, modifying localized thermal regimes, and providing niches for biological activity.

Chapter 12 deals with the effects of biota on soil formation. Two field studies that illustrate the direct impact of trees on the spatial distribution of trace metal concentrations in uncontaminated forest soils are described.

The length of time needed to convert geological material into a soil varies, depending on the nature of the material and its interaction with climate,

topography and living organisms. A given period of time may produce large changes in one soil and have little effect on another soil. Some horizons differentiate before others, especially those at the surface which may take only a few decades to form in unconsolidated deposits. Middle horizons differentiate more slowly, particularly when a considerable amount of translocation of material or weathering is necessary, some taking several millennia to develop. Chapter 13 examines the evolution of soil properties over time.

Pedogenesis is also possible in the absence of biota, as documented in some ice-free areas of the Arctic and Antarctic regions. On this basis, the physically and chemically weathered substrata of the Moon and Mars must be considered soils. Chapter 14 discusses extraterrestrial soils, as well as a variety of factors that can affect soil genesis on Earth, in addition to the five soil-forming factors first proposed by Dokuchaev.

Soil functions and land uses are described in Chapter 15. Several ideas are provided that will allow soil scientists to be better prepared for collaboration in the interdisciplinary arena. The pressure of a constantly growing population along with its demands and activities increasingly threaten the soil as a slowly renewable resource. Major problems arise from the cumulative use of land for living space, infrastructure, food and industrial production. Chapter 16 examines the most common issues due to physical degradation of soil, while Chapter 17 discusses the various forms of chemical degradation and their causes. The non-linearity of many soil processes and the spatial and temporal variability associated with their kinetics is particularly worthy of further investigation. Some of the questions that more urgently need an answer from soil science are discussed in Chapter 18.

Finally, this book includes an Appendix that provides: (a) the rudiments for naming genetic horizons, (b) a list of diagnostic horizons, properties and soil materials of the World Reference Base for Soil Resources (WRB) with their Soil Taxonomy (ST) equivalents, (c) description of the 32 WRB Reference Soil Groups, and (d) an approximate correlation of the WRB Reference Soil Groups with the 12 Soil Orders of Soil Taxonomy.

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