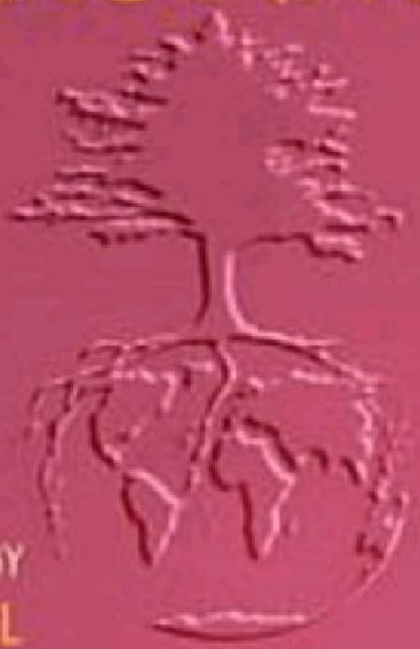
Encyclopedia of Soils in the Environment



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Volume Two

ENCYCLOPEDIA OF SOILS IN THE ENVIRONMENT

FOUR-VOLUME SET

by Daniel Hillel (Editor-in-Chief)

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Book Description

More than ever before, a compelling need exists for an encyclopedic resource about soil the rich mix of mineral particles, organic matter, gases, and soluble compounds that foster both plant and animal growth. Civilization depends more on the soil as human populations continue to grow and increasing demands are placed upon available resources.
The Encyclopedia of Soils in the Environmentis a comprehensive and integrated consideration of a topic of vital importance to human societies in the past, present, and future.

This important work encompasses the present knowledge of the world's variegated soils, their origins, properties, classification, and roles in the biosphere. A team of outstanding, international contributors has written over 250 entries that cover a broad range of issues facing today's soil scientists, ecologists, and environmental scientists.
This four-volume set features thorough articles that survey specific aspects of soil biology, ecology, chemistry and physics. Rounding out the encyclopedia's excellent coverage, contributions cover cross-disciplinary subjects, such as the history of soil utilization for agricultural and engineering purposes and soils in relation to the remediation of pollution and the mitigation of global climate change.

This comprehensive, yet accessible source is a valuable addition to the library of scientists, researchers, students, and policy makers involved in soil science, ecology, and environmental science.

Also available online via ScienceDirect featuring extensive browsing, searching, and internal cross-referencing between articles in the work, plus dynamic linking to journal articles and abstract databases, making navigation flexible and easy. For more information, pricing options and availability visit www.info.sciencedirect.com.

* A distinguished international group of editors and contributors
* Well-organized encyclopedic format providing concise, readable entries, easy searches, and thorough cross-references
* Abundant visual resources — photographs, figures, tables, and graphs — in every entry
* Complete up-to-date coverage of many important topics — essential information for scientists, students and professionals alike

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FOREWORD

The *Encyclopedia of Soils in the Environment* is a vitally important scientific publication and an equally important contribution to global public policy. The *Encyclopedia* brings together a remarkable range of cutting-edge scientific knowledge on all aspects of soil science, as well as the links of soils and soil science to environmental management, food production, biodiversity, climate change, and many other areas of significant concern. Even more than that, the *Encyclopedia* will immediately become an indispensable resource for policy makers, analysts, and students who are focusing on one of the greatest challenges of the 21st century. With 6.3 billion people, our planet is already straining to feed the world's population, and is failing to do so reliably in many parts of the world. The numbers of chronically poor in the world have been stuck at some 800 million in recent years, despite long-standing international goals and commitments to reduce that number by several hundred million. Yet the challenge of food production will intensify in coming decades, as the human population is projected to rise to around 9 billion by mid-century, with the increased population concentrated in parts of the world already suffering from widespread chronic under-nourishment.

Unless the best science is brought to these problems, the situation is likely to deteriorate sharply. Food production systems are already under stress, for reasons often related directly to soils management. In Africa, crop yields are disastrously low and falling in many places due to the rampant depletion of soil nutrients. This situation needs urgent reversal, through increasing use of agro-forestry techniques (e.g. inter-cropping cereals with leguminous nitrogen-fixing trees) and increasing the efficient applications of chemical fertilizers. In other impoverished, as well as rich, parts of the planet, decades of intensive agriculture under irrigation have led to salinization, water-logging, eutrophication of major water bodies, dangerous declines of biodiversity and other forms of environmental degradation. These enormous strains are coupled with the continuing pressures of tropical deforestation and the lack of new promising regions for expanding crop cultivation to meet the needs of growing populations. Finally, there looms the prospect of anthropogenic climate change. Global warming and associated complex and poorly understood shifts in precipitation extremes and other climate variables all threaten the world's natural ecosystems and food production systems in profound yet still imperfectly understood ways. The risks of gradual or abrupt climate change are coupled with the risks of drastic perturbations to regional and global food supplies.

The *Encyclopedia* offers state-of-the-art contributions on each of these challenges, as well as links to entries on the fundamental biophysical processes that underpin the relevant phenomena. The world-scale and world-class collaboration that stands behind this unique project signifies its importance for the world community. It is an honor and privilege for me to introduce this path-breaking endeavor.

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PREFACE

The term 'soil' refers to the weathered and fragmented outer layer of our planet's land surfaces. Formed initially through the physical disintegration and chemical alteration of rocks and minerals by physical and biogeochemical processes, soil is influenced by the activity and accumulated residues of a myriad of diverse forms of life. As it occurs in different geologic and climatic domains, soil is an exceedingly variegated body with a wide range of attributes.

Considering the height of the atmosphere, the thickness of the earth's rock mantle, and the depth of the ocean, one observes that soil is an amazingly thin body – typically not much more than one meter thick and often less than that. Yet it is the crucible of terrestrial life, within which biological productivity is generated and sustained. It acts like a composite living entity, a home to a community of innumerable microscopic and macroscopic plants and animals. A mere fistful of soil typically contains billions of microorganisms, which perform vital interactive biochemical functions. Another intrinsic attribute of the soil is its sponge-like porosity and its enormous internal surface area. That same fistful of soil may actually consist of several hectares of active surface, upon which physicochemical processes take place continuously.

Realizing humanity's utter dependence on the soil, ancient peoples, who lived in greater intimacy with nature than many of us today, actually revered the soil. It was not only their source of livelihood, but also the material from which they built their homes and that they learned to shape, heat, and fuse into household vessels and writing tablets (ceramic, made of clayey soil, being the first synthetic material in the history of technology). In the Bible, the name assigned to the first human was Adam, derived from 'adama,' meaning soil. The name given to that first earthling's mate was Hava (Eve, in transliteration), meaning 'living' or 'life-giving.' Together, therefore, Adam and Eve signified quite literally 'Soil and Life.'

The same powerful metaphor is echoed in the Latin name for the human species – Homo, derived from humus, the material of the soil. Hence, the adjective 'human' also implies 'of the soil.' Other ancient cultures evoked equally powerful associations. To the Greeks, the earth was a manifestation of Gaea, the maternal goddess who, impregnated by Uranus (god of the sky), gave birth to all the gods of the Greek pantheon.

Our civilization depends on the soil more crucially than ever, because our numbers have grown while available soil resources have diminished and deteriorated. Paradoxically, however, even as our dependence on the soil has increased, most of us have become physically and emotionally detached from it. Many of the people in the so-called 'developed' countries spend their lives in the artificial environment of a city, insulated from direct exposure to nature, and some children may now assume as a matter of course that food originates in supermarkets.

Detachment has bred ignorance, and out of ignorance has come the delusion that our civilization has risen above nature and has set itself free of its constraints. Agriculture and food security, erosion and salination, degradation of natural ecosystems, depletion and pollution of surface waters and aquifers, and decimation of biodiversity – all of these processes, which involve the soil directly or indirectly – have become abstractions to many people. The very language we use betrays disdain for that common material underfoot, often referred to as 'dirt.' Some fastidious parents prohibit their children from playing in the mud and hurry to wash their 'soiled' hands when the children nonetheless obey an innate instinct to do so. Thus soil is devalued and treated

as unclean though it is the terrestrial realm's principal medium of purification, wherein wastes are decomposed and nature's productivity is continually rejuvenated.

Scientists who observe soil closely see it in effect as a seething foundry in which matter and energy are in constant flux. Radiant energy from the sun streams onto the field and cascades through the soil and the plants growing in it. Heat is exchanged, water percolates through the soil's intricate passages, plant roots extract water and transmit it to their leaves, which transpire it back to the atmosphere. Leaves absorb carbon dioxide from the air and synthesize it with soil-derived water to form the primary compounds of life. Oxygen emitted by the leaves makes the air breathable for animals, which consume and in turn fertilize plants.

Soil is thus a self-regulating bio-physio-chemical factory, processing its own materials, water, and solar energy. It also determines the fate of rainfall and snowfall reaching the ground surface – whether the water thus received will flow over the land as runoff, or seep downward to the subterranean reservoir called groundwater, which in turn maintains the steady flow of springs and streams. With its finite capacity to absorb and store moisture, and to release it gradually, the soil regulates all of these phenomena. Without the soil as a buffer, rain falling over the continents would run off entirely, producing violent floods rather than sustained river flow.

Soil naturally acts as a living filter, in which pathogens and toxins that might otherwise accumulate to foul the terrestrial environment are rendered harmless. Since time immemorial, humans and other animals have been dying of all manner of disease and have then been buried in the soil, yet no major disease is transmitted by it. The term *antibiotic* was coined by soil microbiologists who, as a consequence of their studies of soil bacteria and actinomycetes, discovered streptomycin (an important cure for tuberculosis and other infections). Ion exchange, a useful process of water purification, also was discovered by soil scientists studying the passage of solutes through beds of clay.

However unique in form and function, soil is not an isolated body. It is, rather, a central link in the larger chain of interconnected domains and processes comprising the terrestrial environment. The soil interacts both with the overlying atmosphere and the underlying strata, as well as with surface and underground bodies of water. Especially important is the interrelation between the soil and the climate. In addition to its function of regulating the cycle of water, it also regulates energy exchange and surface temperature.

When virgin land is cleared of vegetation and turned into a cultivated field, the native biomass above the ground is often burned and the organic matter within the soil tends to decompose. These processes release carbon dioxide into the atmosphere, thus contributing to the earth's greenhouse effect and to global warming. On the other hand, the opposite act of reforestation and soil enrichment with organic matter, such as can be achieved by means of conservation management, may serve to absorb carbon dioxide from the atmosphere. To an extent, the soil's capacity to store carbon can thus help to mitigate the greenhouse effect.

Thousands of years are required for nature to create life-giving soil out of sterile bedrock. In only a few decades, however, unknowing or uncaring humans can destroy that wondrous work of nature. In various circumstances, mismanaged soils may be subject to erosion (the sediments of which tend to clog streambeds, estuaries, lakes, and coastal waters), to leaching of nutrients with attendant loss of fertility and eutrophication of water bodies, to waterlogging and impaired aeration, or to an excessive accumulation of salts that may cause a once-productive soil to become entirely sterile. Such processes of soil degradation, sometimes called 'desertification,' already affect large areas of land.

We cannot manage effectively and sustainably that which we do not know and thoroughly understand. That is why the tasks of developing and disseminating sound knowledge of the soil and its complex processes have assumed growing urgency and importance. The global environmental crisis has created a compelling need for a concentrated, concise, and definitive source of information – accessible to students, scientists, practitioners, and the general public – about the soil in all its manifestations – in nature and in relation to the life of humans.

Daniel Hillel
Editor-in-Chief
May 2004

INTRODUCTION

The *Encyclopedia of Soils in the Environment* contains nearly 300 articles, written by the world's leading authorities. Pedologists, biologists, ecologists, earth scientists, hydrologists, climatologists, geographers, and representatives from many other disciplines have contributed to this work. Each of the articles separately, and all of them in sequence and combination, serve to summarize and encapsulate our present knowledge of the world's variegated soils, their natural functions, and their importance to humans.

Concise articles surveying specific aspects of soils (soil genesis, soil chemistry and mineralogy, soil physics and hydrology, and soil biology) are complemented by articles covering transdisciplinary aspects, such as the role of soils in ecology, the history of soil utilization for agricultural and engineering purposes, the development of soil science as a discipline, and the potential or actual contributions of soils to the generation, as well as to the mitigation, of pollution and of global climate change.

This comprehensive reference encompasses both the fundamental and the applied aspects of soil science, interfacing in general with the physical sciences and life sciences and more specifically with the earth sciences and environmental sciences.

The *Encyclopedia of Soils in the Environment* manifests the expanding scope of modern soil science, from its early sectarian focus on the utilitarian attributes of soils in agriculture and engineering, to a wider and much more inclusive view of the soil as a central link in the continuous chain of processes constituting the dynamic environment as a whole. Thus it both details and integrates a set of topics that have always been of vital importance to human societies and that are certain to be even more so in the future.

Daniel Hillel
Editor-in-Chief
May 2004

CONTENTS

Contents are given as follows: CHAPTER NAME Author(s) Page number

VOLUME 1

Born in California and raised in Israel, Dr. Daniel Hillel acquired an early and lifelong love of the land and a commitment to understanding and proctecting the natural environment. Through decades of work in some thirty countries, he has become an international authority on sustainable management of land and water resources. Dr. Hillel has served as professor of soil physics, hydrology and the environmental sciences at leading universities in the U.S. and abroad, and has been a consultant to the World Bank and the United Nations. Among the honors he has received are the Chancellor's Meda