Advances in Soil Science

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Advances in Soil Science

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Preface

The purpose of *Advances in Soil Science* is to provide a forum for leading scientists to analyze and summarize the available scientific information on a subject, assessing its importance and identifying additional research needs. A wide array of subjects has been addressed by authors from many countries in the initial ten volumes of the series. The quick acceptance of the series by both authors and readers has been very gratifying and confirms our perception that a need did exist for a medium to fill the gap between the scientific journals and the comprehensive reference books.

This volume is the first of the series devoted entirely to a single topic—soil degradation. Future volumes will include both single-topic volumes as well as volumes containing reviews of different topics of soil science, as in the case of the first ten volumes.

There are increasing concern and attention about managing natural resources, particularly soil and water. Soil degradation is clearly one of the most pressing problems facing mankind. Although the spotlight regarding soil degradation in recent years has focused on Africa, concern about the degradation of soil and water resources is worldwide. The widespread concern about global environmental change is also being linked to severe problems of soil degradation. Therefore, we are indeed pleased that the first volume of the series devoted to a single topic addresses such an important issue.

The current volume is also the first of the series involving a guest editor. Dr. R. Lal was invited to serve as the lead editor for organizing the volume, selecting the authors, and coordinating their efforts. Dr. Lal is eminently qualified because of his wide background of experience. Dr. Lal has worked extensively in India, Australia, North America, and Africa and has traveled widely in many countries. He is currently a Professor of Soil Science at Ohio State University and is clearly one of the world's most knowledgeable scientists concerned with soil degradation. It has been a stimulating and rewarding experience to work with Dr. Lal in editing this volume.

I also want to thank the authors for their excellent contributions and cooperation and the Springer-Verlag staff for their kind assistance and counsel. Finally, and most importantly, I thank the readers for their acceptance and use of *Advances in Soil Science*.

B.A. Stewart
Series Editor

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Soil Degradation: A Global Threat

R. Lal and B.A. Stewart

Introduction

Soil degradation is one of the greatest challenges facing mankind. Although the problem is as old as the settled agriculture, its extent and impact on human welfare and global environment are more now than ever before. It is a major concern for at least two reasons. First, soil degradation undermines the productive capacity of an ecosystem. Second, it affects global climate through alterations in water and energy balances and disruptions in cycles of carbon, nitrogen, sulfur, and other elements. Through its impact on agricultural productivity and environment, soil degradation leads to political and social instability, enhanced rate of deforestation, intensive use of marginal and fragile lands, accelerated runoff and soil erosion, pollution of natural waters, and emission of greenhouse gases into the atmosphere. In fact, soil degradation affects the mere fabric of mankind.

Soil degradation is defined as “the decline in soil quality caused through its misuse by humans.” It is a broad and vague term, however, and refers to a decline in the soil’s productivity through adverse changes in nutrient status and soil organic matter, structural attributes, and concentrations of electrolytes and toxic chemicals. In other words, it refers to a diminution of the soil’s current and/or potential capability to produce quantitative or qualitative goods or services as a result of one or more degradative processes (UNEP, 1982).

Geographic Extent of Soil Degradation

Soil degradation has plagued mankind for thousands of years. Most ancient civilizations flourished on fertile soils. However, as the soil’s productivity declined, so did cultures and civilizations that depended on it. Archaeological evidence has shown that soil degradation was responsible for the extinction of the Harappan civilization in western India, Mesopotamia in

western Asia, and the Mayan culture in Central America (Olson, 1981). It is estimated that over the millennia as much as two billion hectares of land that were once biologically productive have been rendered unproductive through soil degradation (UNEP, 1986). Furthermore, the current rate of soil degradation is estimated at five to seven million hectares per year, and the annual rate may climb to ten million hectares by the turn of the century (FAO/UNEP, 1983). If these statistics are nearly correct, there is a need for immediate action by the international community to do something about it. Planners must develop policies to restore the disturbed ecosystems and ensure that conservation-effective measures are taken to preserve and enhance the productivity of existing lands.

One of the problems of these statistics is the ambiguity of the term *soil degradation*. Ambiguity can be avoided if we can precisely define critical limits of those index soil properties beyond which crops would not grow. These limits vary among soils, land use and farming systems, climatic conditions, and agro-ecological environments. For example, we do not precisely know the critical level of humified organic matter content for major soils of the world beyond which soil structure collapses. It is the lack of precise knowledge about the critical limits of principal properties that makes one skeptical about the validity of statistical data on the global extent of soil degradation. Nonetheless, the problem is extremely severe and worthy of our immediate attention.

Processes, Factors, and Causes of Soil Degradation

Soil degradation is an outcome of depletive human activities and their interaction with natural environments. Processes of soil degradation are the mechanisms responsible for the decline in soil quality. There are three principal types of degradation: physical, chemical, and biological. Each of these types has different processes of soil degradation (Figure 1).

Physical Degradation

Physical degradation refers to the deterioration of the physical properties of soil. This includes the following:

Compaction and Hardsetting. Densification of soil is caused by the elimination or reduction of structural pores. Increase in soil bulk density is caused by natural and man-induced factors. Hardsetting is a problem in soils of low-activity clays and soils that contain low organic matter content. Soils prone to compaction and hardsetting are susceptible to accelerated runoff and erosion.

Soil Erosion and Sedimentation. Worldwide erosion of topsoil by wind and water exceeds formation at an alarming rate. Desertification, the spread of desert-like conditions, is a direct consequence of wind erosion. Eroded

Figure 1. Types and processes of soil degradation.

soil, usually containing two to five times more organic matter and colloidal fraction than the original soil, causes severe on-site and off-site effects.

Laterization. Laterite is a hard sheet of iron and aluminum-rich duricrust. *Laterization*, therefore, refers to the desiccation and hardening of plinthitic material on exposure and desiccation.

Biological Degradation

Reduction in soil organic matter content, decline in biomass carbon, and decrease in activity and diversity of soil fauna are ramifications of biological degradation. Because of prevailing high soil and air temperatures, biological degradation of soil is more severe in the tropics than in the temperate zone. Biological degradation can also be caused by indiscriminate and excessive use of chemicals and soil pollutants.

Chemical Degradation

Nutrient depletion is a major cause of chemical degradation. In addition, excessive leaching of cations in soils with low-activity clays causes a decline in soil pH and a reduction in base saturation. Chemical degradation is also caused by the buildup of some toxic chemicals and an elemental imbalance that is injurious to plant growth.

The causes of soil degradation are anthropogenic perturbations related to socioeconomic pressures and population growth. These causes trigger human activities or factors responsible for soil degradation. Some important factors are deforestation, cultivation of marginal lands, intensive farming, excessive and indiscriminate use of chemicals, excessive grazing with high stocking rate, population transmigration and infrastructure development in ecologically sensitive areas, etc. These causes and factors are especially rampant in many developing countries of Asia, Africa, and tropical America.

Impact of Soil Degradation

An obvious economic impact of soil degradation is on agricultural productivity. Soil supplies essential nutrients and water, and degradation of capacity and intensity factors of water and nutrient availability affects plant growth. However, the environmental consequences of soil degradation have not been given the emphasis they deserve. Although scientists have recognized the dangers of global warming caused by the burning of fossil fuel, the emission of CO₂ and other greenhouse gases through soil degradation has hitherto been ignored. Radiatively active greenhouse gases emitted by soil-related processes are CO₂, CH₄, CO, N₂O, and NO.

Soil organic matter is a major active reservoir in the global carbon cycle. However, there are few data on its size and turnover related to intensification of diverse farming systems. An immediate response to deforestation and intensive cropping and grazing, especially in the tropics, is the very rapid mineralization of soil organic matter. Structural deterioration and accelerated erosion that follow result in the transport of carbon and nutrients out of an ecosystem. When these nutrients reach rivers, lakes, and streams, they cause pollution and eutrophication. Sediment related carbon is easily ejected into the atmosphere as CO₂. Evaluating the precise magnitude of sediment transport and its impact on the global environment remain to be major challenges to soil scientists, hydrologists, and geographers.

Future Considerations

This volume is an effort to collate the up-to-date information and comprehensive reviews on the principal processes of soil degradation. The volume, comprising eight review papers, is provisionally divided into three sections. The first five chapters address the processes of physical degradation, namely, soil compaction, hardsetting, plinthite and laterization, soil erosion, and soil wetness and anaerobioses. There are two chapters on chemical degradation related to nutrient imbalance and salt buildup. The last chapter is a comprehensive review of biological degradation.

This volume is an important step toward creating awareness of the magnitude and severity of the problem. In addition, however, there is also a need to indicate the urgency of developing methodologies for restoring the productivity of lands that have been rendered unproductive by past mismanagement. The production base can be expanded vastly even if only 50% of the supposedly two billion hectares of new degraded lands can be brought under cultivation. Restoration of degraded lands will also decrease the pressure on bringing new lands under cultivation. A logical followup of this volume may be another volume to address this important aspect of "Restoration of Degraded Soils."

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