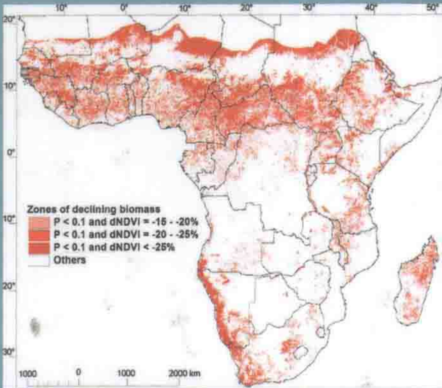
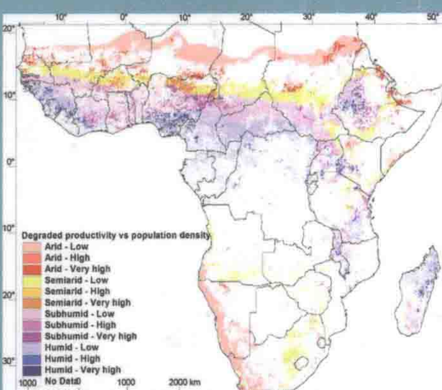


FOOD SECURITY AND SOIL QUALITY



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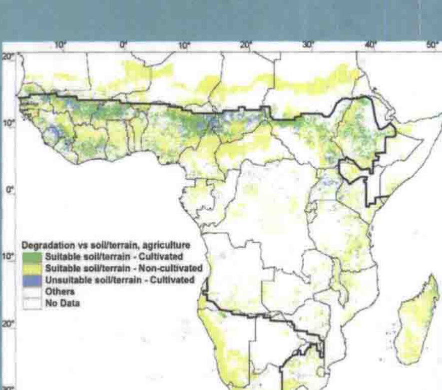

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Food Security and Soil Quality

Edited by
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The serious problem of malnourishment is exacerbated by the deficiency of micronutrients in food grown on degraded/depleted soils. Deficiency of micronutrients in diet is an important cause of morbidity and mortality among children. Health-related problems are especially severe because of an acute deficiency of Zn, Fe, Se, B, I, etc. More serious than land scarcity, the shortage of renewable fresh water resources will be a major constraint even in the near future. Among 30 densely populated countries, which will face severe water shortages by 2025, are India, China, Egypt, Iran, and Nigeria.

Therefore, the focus of this volume of *Advances in Soil Science* is on the sustainable management of soil to enhance soil quality, restore degraded soils, identify site-specific parameters as indicators of soil quality, and describe the impact of soil quality improvements on increasing agronomic production and advancing global food security.

This volume is based on the philosophy that "Poor soils make people poorer, poor people make soils worse, and desperate humanity does not care about sustainability and stewardship." Therefore, we identified world-class soil scientists to contribute articles on issues of global significance. We thank them for sharing their knowledge and experience with us, and for their prompt and timely response.

Rattan Lal
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Editors

Rattan Lal is a professor of soil physics in the School of Natural Resources and Director of the Carbon Management and Sequestration Center, Food, Agricultural, and Environmental Services/Ohio Agriculture Research and Development Center, at the Ohio State University. Before joining Ohio State in 1987, he was a soil physicist for 18 years at the International Institute of Tropical Agriculture, Ibadan, Nigeria. In Africa, Professor Lal conducted long-term experiments on land use, watershed management, soil erosion processes as influenced by rainfall characteristics, soil properties, methods of deforestation, soil-tillage and crop-residue management, cropping systems including cover crops and agroforestry, and mixed/relay cropping methods. He also assessed the impact of soil erosion on crop yield and related erosion-induced changes in soil properties to crop growth and yield. Since joining the Ohio State University in 1987, he has continued research on erosion-induced changes in soil quality and developed a new project on soils and climate change. He has demonstrated that accelerated soil erosion is a major factor affecting emission of carbon from the soil to the atmosphere. Soil-erosion control and adoption of conservation-effective measures can lead to carbon sequestration and mitigation of the greenhouse effect. Other research interests include soil compaction, conservation tillage, mine soil reclamation, water table management, and sustainable use of soil and water resources of the tropics for enhancing food security. Professor Lal is a fellow of the Soil Science Society of America, American Society of Agronomy, Third World Academy of Sciences, American Association for the Advancement of Sciences, Soil and Water Conservation Society, and Indian Academy of Agricultural Sciences. He is a recipient of the International Soil Science Award of the Soil Science Society of America, the Hugh Hammond Bennett Award of the Soil and Water Conservation Society, the 2005 Borlaug Award and 2009 Swamington Award. He also received an honorary degree of Doctor of Science from Punjab Agricultural University, India, and from the Norwegian University of Life Sciences, Aas, Norway. He is a past president of the World Association of the Soil and Water Conservation, the International Soil Tillage Research Organization and Soil Science Society of America. He is a member of the U.S. National Committee on Soil Science of the National Academy of Sciences (1998 to 2002, 2007–). He has served on the Panel on Sustainable Agriculture and the Environment in the Humid Tropics of the National Academy of Sciences. He has authored and coauthored about 1400 research papers. He has also written 13 and edited or coedited 45 books.

B. A. Stewart is a distinguished professor of soil science at the West Texas A&M University, Canyon, Texas. He is also the director of the Dryland Agriculture Institute, and a former director of the USDA Conservation and Production Laboratory at Bushland, Texas; past president of the Soil Science Society of America; and member of the 1990–1993 Committee on Long-Range Soil and Water Policy, National Research Council, National Academy of Sciences. He is a fellow on the Soil Science Society of America, American Society of Agronomy, Soil and Water Conservation

Society, a recipient of the USDA Superior Service Award, a recipient of the Hugh Hammond Bennett Award of the Soil and Water Conservation Society, and an honorary member of the International Union of Soil Sciences in 2008. Dr. Stewart is very supportive of education and research on dryland agriculture. The B.A. and Jane Anne Stewart Dryland Agriculture Scholarship Fund was established in West Texas A&M University in 1994 to provide scholarship for undergraduate and graduate students with a demonstrated interest in dryland agriculture.

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Contents

1 Introduction: Food Security and Soil Quality

R. Lal and B. A. Stewart

Increase in world population, conversion of arable land to nonagricultural uses, and soil degradation and desertification are causing a rapid decline in per capita land area. The global per capita arable land area was 0.45 ha in 1950, 0.35 ha in 1970, 0.28 ha in 1990, and 0.22 ha in 2000. It is projected to progressively decline to 0.15 ha by 2050. There are numerous densely populated countries where the per capita land area is <0.1 ha. For example, the per capita land area in 1990 and 2025, respectively, is estimated at 0.09 and 0.05 ha in Bangladesh, 0.08 and 0.06 ha in China, 0.05 and 0.03 ha in Egypt, 0.17 and 0.07 ha in Pakistan, and 0.13 ha and 0.05 ha in Tanzania. These estimates of per capita land area are based on the assumption of neither additional conversion of arable land to nonagricultural uses nor any abandonment because of soil degradation/desertification. Yet the problems of soil degradation and conversion to urbanization are more severe in developing countries (e.g., Bangladesh, Ethiopia, Pakistan, Tanzania), where natural resources are already under great stress. Therefore, basic necessities of life (e.g., food, feed, fiber, and fuel) for many countries with finite soil resources will have to be met through restoration of degraded soils, and increase in productivity per unit of land area by the use of off-farm inputs (e.g., fertilizer, water, energy).

Although crop yields may be increasing, albeit at a slow rate, the per capita grain consumption in the world is decreasing because the rate of increase in grain production has not kept pace with the rapid rate of population growth. The latter is especially true in South Asia and sub-Saharan Africa, where soil resources are prone to degradation by erosion, nutrient mining, soil organic matter depletion, salinization, decline in soil structure, and industrial pollution. It is estimated that of the 77% of the world's total cropland area that is affected by water erosion (837 out of 1094 Mha), 83% of the land prone to wind erosion (457 out of 548 Mha), 97% of that subject to nutrient mining (132 out of 136 Mha), 94% affected by salinization (72 out of 77 Mha), and 83% of that prone to acidification (5 out of 6 Mha), occur in developing countries. These are also the regions where 99% of the projected increase in world population is expected to occur. Furthermore, farming communities in developing countries consist of resource-poor and small-size (<2 ha) landholders who use extractive farming practices involving little or no off-farm input. Therefore, degradation-induced decline in soil quality has drastic adverse effects on crop yields and agronomic productivity. Fertilizers and other soil amendments are neither available to the resource-poor farmers nor are they sure of their effectiveness.

Soil quality strongly impacts agronomic productivity, use efficiency of input, and global food security. The significance of dependence of food security on soil quality is likely to increase with decrease in per capita land area, increase in extent and severity of soil degradation, and the projected global warming.

Global warming, attributed to atmospheric enrichment of CO_2 and other greenhouse gases due to anthropogenic activities such as fossil fuel combustion and land use conversion, can exacerbate the problems of soil degradation. The projected increase in temperatures and the frequency of extreme events may accentuate the soil erosion risks because of a decline in soil structure and an increase in erosivity by rainfall and wind. Decline in soil structure is attributed to reduction in soil organic matter content and the decline in stability of aggregates.

Emphasis on biofuels may also adversely impact soil quality. Removal of crop residues for use as biofuels, either for direct combustion or for conversion to ethanol, can lead to increased soil erosion risks, increase in susceptibility to crusting and compaction, and depletion of plant nutrients.

There are about 1 billion food-insecure people in the world. Increase in food prices, observed since 2007, has further increased the number of people at risk of hunger and malnutrition. It is now apparent that the UN Millennium Development Goal of cutting hunger by 50% by 2015 will not be met.

Eating food is an agricultural act, and soil is the foundation on which agriculture is practiced. Because humans will always depend on food, management of soils and agriculture must be integral to any initiative toward advancing food security. While money can be created by a speculative bubble, at least temporarily until it bursts as was the case with the global financial crisis experienced in 2007–2008, food has to be grown/produced through judicious management of soil and water resources. For land managers and agricultural scientists to succeed in the war against hunger, degraded and desertified ecosystems must be restored, salinized land must be reclaimed, depleted and impoverished soils must be improved, and those devoid of fauna and flora must be rehabilitated. We can no longer take the soils for granted.

It is often fashionable to blame agriculture for polluting the environment. The Green Revolution, ushered by the late Norman Borlaug who died on September 12, 2009, saved hundreds of millions from starvation by developing and promoting input-responsive varieties. There has been an increase in pollution of water from fertilizers and pesticides, and a decrease in incremental productivity with progressive increase in input of fertilizers. Excessive use of tubewell irrigation has also depleted the groundwater reserves, and that of canal irrigation has created water and salt imbalance. The problem is not with the technology, but using technology without wisdom. It is overfertilization, overuse of pesticides, excessive application of free irrigation water, unnecessary plowing, indiscriminate removal of crop residues, and uncontrolled grazing that have caused the problems. Improvements in agriculture, essential for feeding the world population of 9.2 billion by 2050 and ~10 billion by 2100, has to be a solution to environmental concerns (e.g., water pollution, global warming) rather than the cause. Those who blame agriculture must completely abstain from food just for 24 hours to fully comprehend the experience of those who suffer from food deprivation on a perpetual basis.

Humanity is at the crossroads as far as the global issues of food insecurity, climate disruption, and soil and environmental degradation are concerned. The strategy is to learn and change—alter land use and soil management to restore degraded soils and desertified ecosystems to a desirable stability/quality domain. The two key questions are: (1) How can we implement ways to expand human opportunity and facilitate human learning to sustain soil/ecosystem resilience? (2) How can we develop and implement soil/ecosystem/social resilience, integrated understanding, policies, and action among scientists, economic and public interest groups, and farmers and land managers so that knowledge and science-based action plan is evolved and implemented? The strategy is of moving toward sustainable soil quality and agricultural improvement through research-based policies. Sustainable soil quality management approaches are those which permanently retain the ability of soils to provide ecosystem services and recover after an anthropogenic perturbation. These approaches involve weighing up of options, keeping options open, and creating new opportunities when old options are no longer feasible or become redundant.

2 Managing Soils to Address Global Issues of the Twenty-First Century

R. Lal

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