STRESSES CAUSED BY EDAPHIC FACTORS

Friedrich H. Beinroth
Dept. of Agronomy and Soils, University of Puerto Rico, Mayaguez, PR, USA

Hari Eswaran
World Soil Resources, USDA/NRCS, Washington, DC, USA

Paul F. Reich
World Soil Resources, USDA/NRCS, Washington, DC, USA.

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Summary

Soil, land and climate conditions adverse to food production affect essentially all of the world's land resources. These edaphic constraints are chemical, physical, biologic or climatic in nature and while most of them are intrinsic soil and land properties, some are caused by human activity. These stresses typically occur in a variety of interactive combinations. Also, the same stress may be both adverse and beneficial, depending on the crop grown. About 50 major stress factors were identified, correlated with criteria of soil classification and arranged in a hierarchical key with 25 stress classes. A digital soil map of the world allowed determining the area of all stress classes. A sample map illustrates the global distribution of three important stress factors. The data show that more than half of the world's soils have severe or prohibitive constraints for food production because they are either too dry, too cold, too steep or too shallow. Additional stress factors include aluminum toxicity, salinity, seasonal excess water, acid sulfate conditions, excessive nutrient leaching, and root restricting layers. While some constraints are beyond human control, many of them can conceivably be ameliorated. Frequently, however, the corrective measures required are either economically unfeasible, environmentally undesirable, or both. Moreover, land degradation, mainly due to soil erosion and salinization, reduces the quantity and quality of the agricultural resource base at an alarming rate. Diminishing land resources will thus have to provide the food for a world population that is expected to grow at least through the first half of the twenty-first century. Concerted efforts are therefore needed to develop and

implement policies and practices conducive to protecting the integrity of the world's land resources and mitigating further losses of agricultural productivity. Finally, the phenomena associated with global climate change are additional factors contributing to food insecurity. Although there are positive and negative aspects, the net effect on global food production remains uncertain, but is likely to be more adverse in the lower latitudes.

1. Introduction

Webster's Dictionary defines "edaphic" as "relating to, or determined by, conditions of the soil". (The term "edaphos" was coined by Theophrastus (c. 372-287 BC), a perpatetic philosopher and prominent pupil of Aristotle, to distinguish earth, or soil, from the planet Earth.) However, for the purpose of this article, we have adopted a broader definition and consider edaphic constraints to food production those conditions of soil, land, and climate that adversely affect agricultural productivity.

To varying degrees, essentially all of the world's land resources are affected by such constraints. Moreover, the broadening extent and the increasing severity of some major stress factors result in a further deterioration of the agricultural lands of the world. Yet, this diminishing resource base has to produce the food needed to reduce present hunger levels in the developing countries and will have to meet the nutritional needs of a growing population. The perceived discrepancy between food supply and food demand has been a concern of the scientific community and environmental activists, but efforts to address the dilemma have been largely ineffectual and rhetorical. Thus, the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 issued compelling statements of principle and has created awareness in the political arena. But so far it has not triggered the massive concerted efforts required to confront the problem. Similarly, the commendable UN Convention to Combat Desertification (CCD) has not yet yielded action programs of pragmatic impact. It is encouraging, therefore, that the United Nations Development Programme, the United Nations Environmental Programme, the World Bank, and the World Resources Institute have recently reconfirmed their commitment to making the viability of the world's ecosystems, including agroecosystems, a critical development priority for the twenty-first century.

Within the limitation imposed by the required brevity, this article attempts to describe the constraints, indicate their geographic extent, discuss their causes and consequences, allude to their amelioration, and assess the implications for sustainable food production.

2. Kind of Constraints

The major edaphic constraints to food production are shown in Table 1. As the table shows, we distinguish between natural and anthropic stresses. The former may be either intrinsic soil properties caused by internal soil processes and reactions, or constraints caused by external conditions. Note that some stresses, e.g. soil acidity and erosion, may result from both natural and human-induced conditions.

It should be realized that Table 1 conveys a very simplistic picture. One complication not addressed is that what may be a constraint for one kind of land use, may be an advantage for another. For example, a high ground water table or waterlogging is considered an impediment for most crops, yet paddy rice clearly benefits from such a condition. Similarly, a high concentration of exchangeable aluminum, which is common in some tropical and subtropical soils such as Oxisols and Ultisols, is toxic to many temperate region crops, notably grain cereals, whereas many tropical plants have developed a tolerance for this condition. Additionally, the same condition may have both adverse and favorable effects. Thus, organic carbon contents may impair crop production if they are too high or too low, but are beneficial at moderate levels.

Category	**Examples of Stress Factors**
Natural Stresses	
Stresses caused by internal soil processes	
Chemical conditions	Nutrient deficiencies; excess of soluble salts; salinity and alkalinity; low base saturation; low pH; aluminum and manganese toxicity; acid sulfate condition; high P and anion retention; calcareous or gypseous conditions
Physical conditions	High susceptibility to erosion; steep slopes; shallow soils; surface crusting and sealing; low water-holding capacity; impeded drainage; low structural stability; root restricting layer; high swell/shrink potential
Biological conditions	Low or high organic matter content
Ecosystem conditions	Low soil resilience; natural soil degradation
Stresses caused by external conditions and processes	
Climate-controlled conditions	Soil moisture deficit; extreme temperature conditions and regimes; insufficient length of growing season; waterlogging; excessive nutrient leaching; El Niño events; global warming
Biological conditions	Pests and diseases; high termite population
Catastrophic events	Floods and droughts; landslides; seismic and volcanic activity
Ecosystem conditions	Impaired ecosystem functions and services; loss of soil quality and soil health
Anthropic Stresses	
Chemical conditions	Acidification by acid rain and acidifying fertilizers; contamination with toxins
Physical conditions	Accelerated soil erosion; soil compaction; subsidence of drained organic soils
Biological conditions	High incidence of pests and diseases; allelopathy; loss of predators

Table 1. Edaphic constraints to food production

The stress factors listed in Table 1 typically occur in a multitude of possible combinations. For example, a soil with moisture stress may simultaneously have nutrient deficiencies, surface crusting, and a shallow solum. A further consideration to be taken into account is the quantitative or qualitative level of severity of a constraint, which controls the degree of adverse impact. Finally, there are constraints which defy accurate quantification. The recently advanced concepts of soil quality, soil health, and the resulting soil resilience, although potentially limiting factors of crop production, have yet to be defined in a quantitative manner that is science-based and operational.

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Biographical Sketch

Friedrich H. Beinroth is a professor of soil science in the Department of Agronomy and Soils of the University of Puerto Rico at Mayaguez, Puerto Rico. He earned his doctoral degree at the University of Suttgart in Germany with a thesis based on his soil survey work in the Republic of the Sudan in Africa. He subsequently spent a postdoctoral year with the then Soil Conservation Service of the US Department of Agriculture in various parts of the United States. He joined the faculty of the University of Puerto Rico in 1967.

His professional interests include analogue and systems-based agrotechnology transfer, sustainable land management, carbon sequestration in tropical soils and tropical pedology. He has published extensively on these subjects. His many professional recognitions include the Distinguished Service to Agriculture Award by Gamma Sigma Delta; the International Honor Award by the US Department of Agriculture, Office of International Cooperation and Development ["…for sustained outstanding success in implementing Soil Taxonomy workshops to extend an international system of soil classification to tropical and subtropical soils, thereby providing for enhanced agrotechnology transfer in developing countries.]; and the International Soil Science Award by the Soil Science Society of America ["… in recognition of scientific contributions to soil science in the international sector."].