Enhancing Soil and Water Resources to Grow More Food in the Future

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We have all seen the documentaries - decaying ruins of ancient cities surrounded by desolate wastelands. Such striking visual images are contrasted by ancient writings providing detailed accounts of the agricultural productivity of these civilizations and lead one to ask "How could agriculture and the population it supported have once flourished on these now barren lands?" Jared Diamond in his recent bestseller "Collapse – How Societies Choose to Fail or Succeed (Viking Press, 2005) chronicles how past cultures addressed environmental threats and repeatedly mentions soil (degraded by erosion, loss of fertility, or salinization) and water (drought, flood, or disease vector) as key factors contributing to the collapse of civilizations. Again and again examples are presented of how exploitation of soil and water resources enabled adequate food production that allowed civilizations to become established and thrive only to see them collapse due to exhaustion or degradation of the very natural resources that enabled their creation.

A current survey of the global environmental landscape quickly identifies numerous areas for concern. One of the greatest concerns surrounds fresh water – changes in its distribution, availability, and quality. There is the additional foreboding of potential climate change effects and the as yet uncertain future climate conditions that may further stress land, water, and air resources. With a relentlessly increasing world population and expectations of a greater distribution of affluence it is prudent to consider whether our soil and water resources will be capable of producing the staples necessary to sustain the global population. Evidence from professional (e.g. Science special issue on Soils 11 June 2004) and popular press sources (e.g. National Geographic article "Our Good Earth" September 2008) suggest a growing awareness that too many soils have already been degraded leaving prospects for significantly increasing food production to meet rising demand seriously in doubt.

Soil and water are the intimate partners upon which terrestrial ecosystems exist. Surface soil properties determine whether rainfall is partitioned between surface runoff and infiltration. Any contaminants carried with the water into the soil are likely to be absorbed or transformed before leaving the root zone to replenish groundwater resources. Healthy, well-managed soils are less susceptible to erosion so surface runoff will carry little sediment or dissolved contaminants to pollute surface waters. However, this idealized functioning of soil as "nature's water filter" is only relevant if the soil itself has not been physically, chemically, or biologically impaired. The extent of global soil degradation was summarized by the United Nations Environment Program project GLASOD (Global Assessment of Soil Degradation) which published its report in 1991. This assessment identified that even productive soils such as those of the Midwestern U.S. have nonetheless been degraded from their natural condition and their ability to sustain the current level of agricultural productivity or increase that productivity to meet global food demand is in question. Increasing the intensity of production practices including increased tillage, fertilizer application, and pesticide usage to meet growing demand for agricultural products will further stress the ability of cultivated soils to protect or restore surface and subsurface water resources.

Fortunately, restoration of soil functionality and enhancing soil productivity are not only achievable but provide an opportunity to contribute to climate change mitigation. One of the greatest effects of past cultivation practices was the loss of soil organic matter. Current levels of soil organic matter in Midwestern soils are approximately one-half of the pre-cultivation levels. The "humus" of soil is not only a key component of carbon and nutrient cycling processes but also has a pivotal role in maintaining the resiliency of soil particle arrangement or soil structure. Soil structure in turn has a profound influence on soil water movement and water retention for plant uptake and numerous biological and chemical processes. Management practices that increase soil organic matter content tend to make soils more effective in nutrient cycling and more resilient to climatic extremes like flood and drought and ultimately more productive in the long-term. All of these benefits can be achieved by employing practices that encourage carbon sequestration in soils. For example, a recent global data review (West and Post, Soil Sci. Soc. Am. J. 66:1930-1946) indicated that conversion to no-tillage and enhancement of crop rotation complexity increased soil organic carbon an average 57 and 20 g C m^{-2} yr^{-1} for periods of 15-20 and 40-60 years, respectively.

Clearly, enhancing soil organic matter has multiple benefits for food security, water quality, and climate change mitigation. If the multiple benefits of increasing soil organic matter content are well known, why have efforts to increase soil carbon sequestration not met with greater success? Modern agriculture has tended to rely on increasing inputs (fuel, fertilizer, pesticides, and crop genetics) to maintain or increase productivity. Until very recently, economic considerations favored increased investment in these inputs compared to other practices including those with greater carbon sequestration potential (reduced tillage, organic nutrient sources, crop rotations, and perennial crops) that are often cheaper to employ but involve greater risk, reliance on internal biological processes, and more systematic management decisions. The evolving global food crisis and dramatic volatility in energy prices encourage a thoughtful reassessment of current soil management practices. In 2009 the Soil Science Society of America will sponsor a Bouyoucos Conference on "Soil Stewardship in an Era of Climate Change" to address issues of land management from both scientific and ethical perspectives. An interdisciplinary group of experts including philosophers, policy analysts, agronomists, and soil scientists will explore the current trends in soil quality, the economic and ethical implications of different land use options, and strategies to better communicate the potential challenges and consequences for soil quality presented by climate change. Meeting the growing global demand for agricultural products will require greater awareness of the essential role of healthy soils and clean water and a renewed commitment to long-term sustainable practices of food and fiber production.