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CONTENTS

Cover crops with limited irrigation can increase yields, crop quality, and nutrient and water use efficiencies while protecting the environment.

On the Cover
Satellite image of Napa Valley courtesy of DigitalGlobe. NCDC Imaging provides GIS and remote sensing applications for natural resource management using DigitalGlobe images.

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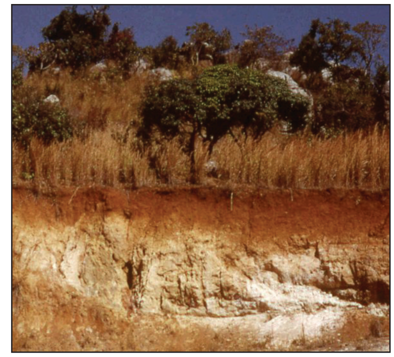
Readers' forum



Roadside cutting in Malawi.
Photo by T. Francis Shaxson.

THINK LIKE A ROOT, THINK LIKE A RIVER

The editor's review of earth scientist David R. Montgomery's book, *Dirt: The Erosion of Civilizations*, followed by Leonard C. Johnson's letter concerning circular citations of "affordable rates of soil loss" (both in the May/June 2007 issue), provoked me to express my concern about the emphases that still appear to dominate thinking about soil conservation.

For a long time I have considered that progress in conservation of soil and water, as applied to agriculture at least, is commonly held back by a "log-jam" in thinking caused by the following:

1. A predominantly geologic/physical/chemical emphasis in describing soil. Although Hans Jenny listed organisms among the soil-forming factors, their significant contributions appear very often to have been given minimal attention.
2. A preoccupation with net rate of erosional soil loss on the assumption that severity of loss of soil productivity is primarily and in some way directly caused by this. It needs to be asked *why* runoff and erosion occur and whether hindering downslope soil movement by physical and/or vegetative methods adequately addresses the joint problems of decline in productivity (or the rising costs of maintaining it) on the one hand and of worsening hydrologic conditions of stream flow and groundwater recharge on the other.

Agriculture's outputs depend primarily on plants' production and therefore on the functioning of their root systems. A root's top-down perception of soil as a medium in which to grow and function is significantly different in emphasis from a geologist's bottom-upward perception of soil as an upper layer of the earth's crust modified by weathering.

Roots cannot function effectively if the medium they penetrate is inimical and if it does not retain sufficient available water. River flows cannot be suave throughout the year if rainwater does not infiltrate, and the consequent runoff induced by soil impermeabilization heightens flood peaks in rainy seasons and represents a loss of potential volume of flow in dry seasons.

The entry of water into soil, benefiting both plant production and river regimes, depends on the ongoing presence of an adequate porosity throughout a soil profile. In this regard, the interstitial spaces between soil mineral particles and aggregates may be equally—or more—significant to the dynamics of root-growth and water movement as are the solid components of the soil. The loss of this porosity, whether due to compaction, to pulverization or to collapse following loss of organic matter, represents a loss of soil's usefulness. Demolishing a building in situ results in not just a pile of all the physical rubble but the loss of the spaces—rooms, corridors, kitchens, etc.—in which interesting dynamic things formerly occurred and which gave the building its usefulness. Even the possibility of "recycling" the rubble disappears if it is carted away. So it is with soil.

Nevertheless, the porosity of formerly productive soil, once damaged in this way, is capable of being repeatedly regenerated by soil-inhabiting organisms, including plants, fungi, and animals, interacting over time with the other chemical, physical and hydric factors of soil, which together determine the characteristics of its productivity. Such regeneration can occur as much in the root zones of disturbed but well-managed soils as in their undisturbed conditions, as for instance in native forests and grasslands.

It is apparent that soil-inhabiting organisms make their own habitats from the surface downward, as indicated by the photo of a roadside cutting in Malawi. I infer that leachates from the biotic transformations of organic matter may be contributing to the release of nutrient ions from the mineral particles in the profile. If so, this suggests that useful soil is probably forming—and can be formed when fostered appropriately—much more quickly from the top downward than is assumed behind the "mini-miasma of circular and interlocking citations" criticized by Leonard C. Johnson.

Striking and widespread examples of positive improvements in the maintenance of soil productivity can rightfully be attributed to the spread of well-managed rotational zero-tillage systems that achieve "top-down" enhancement. In such systems the maintenance of a crop-residue cover over the soil surface not only buffers against high-energy rainfall impact but also provides a regular supply of organic substrate for biotic activity in the soil, with several beneficial consequences. These include nutrient recycling and ongoing formation and re-formation of varied soil porosity, with attendant entry, retention, and movement of water. Following elimination of tillage from these production systems, soil organic matter can accumulate (benefiting the soil biota) rather than decline, as formerly happened due to excessive aeration, more-rapid transformation of organic matter by the soil biota, and a net loss of carbon, as its dioxide, to the atmosphere.

Herein lie the biologic roots of sustainability, which has kept much land productive over centuries, despite any past and present periods of people's mismanagement of their soil resources.

It is useful to "think like a root, think like a river" to perceive what characteristics of soil are needed so that landscapes can continue producing the vegetation and water on which, ultimately, we all depend. In this scenario, loss of soil porosity is not only a primary cause of damage to the root environment but also predisposes soils to suffer runoff and erosion as a consequence of such damage.

Understanding and managing the integrated functioning of the carbon cycle with the hydrologic cycle and all the ecological consequences therefrom deserve much greater attention now, in our attempts to maintain soils' productivity and to secure water supplies, than the circular and less-than-fruitful debates and experiments about "affordable rates of soil loss."

The heresies uttered above have many implications for priorities in research, extension, training, policy making, funding, and for the sustainability and stability of farming in a changing world.

T. Francis Shaxson
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Hugh Hammond Bennett Award recipient, 1995

THE QUEST FOR ANSWERS LEADS TO MORE QUESTIONS

We would like to share a bit of early soil erosion research history and consider its past and future implications.

For many, the first recognition of the consequences of soil misuse came during America's Great Dust Bowl of the 1930s. Hugh Hammond Bennett was well aware of soil ruination and had written steadily about it throughout the 1920s; his warnings were not heeded. In 1930, largely in response to Bennett's soil conservation campaign, Texas Representative J.P. Buchanan attached an amendment to the US appropriations bill authorizing the USDA to establish a series of soil erosion experiment stations.

The recognition of the consequences of soil erosion had come even earlier as a surprise to an undergraduate student. In 1915, Rensselaer W. McClure, working under the guidance of Professor Merritt F. Miller at the University of Missouri–Columbia, was directed to measure the rainfall and runoff in small agronomic plots. After the first rain event, McClure, wanting to correctly measure runoff, asked Miller what to do with all the mud in the barrel used to collect runoff. Neither McClure nor Miller had expected the magnitude of soil erosion that occurred on soil cultivated for annual agronomic crops. Russell M. Vifquain, a graduate student, developed four plots in 1916 to evaluate soil moisture and runoff. Because of McClure's mud and Vifquain's study, in 1917 Frank L. Duley under the direction of Miller installed the first seven soil erosion plots in Columbia. Bennett used the results from the Missouri erosion plots to lobby Congress to establish erosion experiment stations around the United States. Miller said of this early work, "This is an example of a simple investigation, developed somewhat accidentally that provided much needed information at a time when important use could be made of it."

Great soil and water conservation benefits have been produced from results of these erosion experiment stations. Of primary importance was the development of the Universal Soil Loss Equation (USLE) and the many models derived from this work. The importance of their data in developing effective conservation plans that tailor conservation practices to the land to reduce erosion to tolerable levels cannot be understated. Nationally, USLE-estimated data are used to produce the National Resource Inventory (NRI) estimates of conservation needs.

As great as this work is, we worry a bit that all who use this information may not realize its limitations. Soil loss estimates from USLE models only estimate the long-term average annual sheet (interrill) and rill from a standard plot less than 100 feet long. What would the NRI maps of soil erosion look like if estimates of ephemeral and gully erosion formation and erosion estimation were also included? What would NRI map estimates of actual (real time) sediment transport to surface waters show? We would like to find out and believe other conservationists would as well.

New work is being done by researchers at the Massachusetts Institute of Technology who are developing channel-hillslope integrated landscape development models that simulate erosion and sedimentation in river basins. Ongoing work at Vanderbilt University may dispel misconceptions about how rain splash transport occurs. Imagine that—something we thought Ellison had described more than 50 years ago. The more we learn, the more we realize that we have even more to learn.

In his 2004 SWCS conference keynote address, "Soil Conservation and SWCS: A Forty-Year Retrospective," Max Schnepf identified challenges that currently confront our community. He opined that while "our movement has enjoyed a reasonable degree of political success, success on the technical side is less apparent." He suggested that technical issues will "demand the attention of NRCS and other institutions that traditionally have possessed responsibility for conservation technology development and transfer." He also argued, "To effectively address this issue will likely require added commitments from other partners and constituencies in position to help." Perhaps SWCS should consider this challenge and work to sponsor an international effort across all disciplines, comparing the advantages of the many approaches for estimating soil and water loss including use of such models as RUSLE2, WEPP, and EUROSEM and those from geologic disciplines. Such an effort would be beneficial to advancing our societal goals to "improve ways to use land that sustains its productive capacity and protects the environment." This could strengthen the conservation connection between scientists, conservationists, and landowners.

In 2004, Jocelyn Kaiser wrote in *Science,* "Soil degradation in all its nefarious forms is not a prelude to mass starvation, as analysts once feared. Nevertheless, it is eroding crop yields and contributing to malnourishment in many corners of the globe." Conservation of soil productivity and protection of environmental quality remain our primary goals. While much has been learned from work based on results from the soil erosion experiment stations, our knowledge of the processes is not yet perfect, and thus our conservation efforts are not as effective as they might be. Recognizing this problem is a step in the right direction for improved soil and water conservation, improved productivity, and a better environment.

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