IT'S NOT JUST ABOUT CLIMATE CHANGE — WHAT ABOUT SOILS?

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Vladimir Vernadsky was one of the giants of geochemistry. Considered the founder of the field of biogeochemistry and a true pioneer in "whole Earth" studies, he realized by 1945 that "Man under our very eyes is becoming a mighty and ever-growing geological force." In the intervening 65 years, his "ever-growing force" has become a tidal wave. The global population has been increasing exponentially since the beginning of the industrial revolution, and as a result has increased by nearly a factor of three between 1945, when his observation was published, and today (see figure). Current projections anticipate a population exceeding 9 billion by 2050. This explosive human population growth has been fueled by ancient hydrocarbons and has come with high costs. Most Earth scientists are concerned with the implications of the rapid accumulation of greenhouse gases in the atmosphere. The consequences include a climate state without polar ice, acidifying oceans, and increasingly variable water fluxes. The rate and extent of these and many other negative climate-related impacts, and how to mitigate them, have caused a vigorous discussion on climate change that is in the news on a nearly daily basis.

However, as a society we are much less aware of another major impact of this rapid increase in human population. Without seeking to minimize the significance of climate change, I point out that land-use impacts associated with the dramatic post–industrial revolution population increase currently exceed climate impacts at most scales. Prominent among these land-use issues is soil degradation, which is highly consequential for the obvious reason that we rely on soil to grow our food.

History teaches us that inattention to soil conservation can have disastrous consequences. One emblematic example of many that could be cited took place in the United States. Until the early 19th century, prairie grasses with deep root systems covered the central plains of the United States. These deeply rooted grasses held the soil in place and served as a water storage system that afforded drought resistance. In 1838, John Deere, a blacksmith, developed a plow that would cut through the dense prairie-grass roots, opening up the plains to extensive wheat farming. Wheat farming flourished, particularly during the late 1920s, aided by increased mechanization and a series of wetter than average years. But when an intense drought affected the region in the 1930s, the soil, which now lacked deeply rooted native grasses, dried up. Billions of tons of topsoil blew away, creating the "dust bowl." The exodus of population from the region was the largest migration in American history. By 1940, 2.5 million people had emigrated from the plains states. This dust bowl episode led to a focus on soil conservation practices and eventually to approaches such as no-till agriculture. Despite improvements brought about by conservative agricultural practices, soil erosion by water and wind on cropland in the United States was still over 1.7 billion tons per year in 2007[1].

Soil degradation can also occur via chemical processes, including salinization, which is the accumulation of salts in soil. Salinization occurs in irrigated arid and semi-arid regions where rainfall is insufficient to leach salts from the root zone. Many agricultural crops have limited tolerance for elevated soil salinity, rendering impacted soils unsuitable for farming. Salinization is currently a major concern in several regions of the world, including parts of western and southern Australia and the San Joaquin Valley in the western United States. Taken to its extreme, salinization has played a role in the fall of civilizations. Mesopotamia has been called the cradle of civilization. One of the earliest city states in this region, with a dense population, full-time bureaucracy, military, and economically stratified society, was Uruk. Founded around 5000 BCE, it flourished until around the third millennium BCE. At about 2900 BCE, it may have been the largest city in the world. Uruk's complex society was possible because of sedentary agriculture that produced an excess of food[2]. Today the site of this former center of early civilization is a desolate desert landscape, the result in large part of irrigation practices and climatic conditions that led to salinization of the soils.

These historical examples illustrate how reduced soil fertility as a result of land-use practices has had deleterious impacts on regional-scale societies. However, the population explosion of the 20th century and beyond has made soil degradation a global problem with foreboding consequences. Humans are causing widespread physical degradation of soil by sealing, compaction, and erosion. One analysis[3] describes the sealing of soil by buildings and roads in western Europe and compaction of soil in eastern Europe by Soviet-era intensive tillage as major concerns. However, it is the loss of soil fertility by soil erosion due in large part to conventional agricultural practices that is a problem of global consequence. Mainly as a result of agriculturally induced erosion, humans may now be an order of magnitude more important at moving sediment than the sum of all natural processes[4,5]. An extensive compilation of soil formation and erosion rates[6] documents that soil production by natural weathering processes and geologic erosion are approximately in equilibrium. In stark contrast, soil erosion by conventional agriculture is up to several orders of magnitude more rapid than these natural processes. By one estimate, between one-third and one-half of the ice-free Earth surface has already been transformed by human action[7]. The United Nations–sponsored GLASOD (Global Assessment of Human Induced Soil Degradation) study[8] estimated that about 15% of the Earth's ice-free surface is afflicted by some form of land degradation. A more recent assessment using a different methodology likewise documents extensive land degradation[9]. All this matters because we will require more land to feed our expanding population. The estimated areal increase in cropland required to feed the increased population on the planet between now and 2050 is roughly the size of Brazil [10].

There is no doubt that the combined impacts of humanity on the planet justify Vernadsky's prophetic characterization of our species as a mighty geologic force. In fact, I am sure that if he were alive today, he would endorse the suggestion that we have entered a new geologic era, the Anthropocene[11]. But it is not enough just to understand the scope of civilization's transformation of the planet. We should also heed the warning of one of America's great conservationists, Aldo Leopold, who wrote in 1933, "The reaction of land to occupancy determines the nature and duration of civilization."

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