In Focus: Soils

NPS/NEAL HERBERT

Celebrating soils across the National Park System

Figure 1. Cryptobiotic soil crusts at Arches National Park accumulate very slowly as cyanobacteria, algae, lichens, and other microscopic organisms grow in the desert climate. This one has become home for a young fish hook cactus. These fragile soils can take decades to recover from a careless footprint.

By Susan Southard and Gregory Eckert

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biodiversity, climate change, ecosystem services, soil carbon sequestration, soils

THE 68TH UNITED NATIONS GENERAL Assembly declared 2015 the International Year of Soils (FAO 2015). The goal of this designation was to increase awareness about the fundamental relevance of soils for human societies. The declaration also called for the initiation or renewal of policies and actions aimed at sustaining soils globally. Because they are slow to recover from disturbance, soils are considered a nonrenewable resource (fig. 1) and must be preserved in order to secure a sustainable future for humanity. The value of conserving soils lies with the fact that soils are the basis for (1) producing healthy food; (2) cultivating vegetation for animal feed, fiber, fuel, and medicinal products; (3) supporting Earth's biodiversity; (4) combating and adapting to climate change; and (5) storing and filtering water. As the International Year of Soils comes to a close and the National Park Service begins its centennial year, we hope to stimulate appreciation for the diverse and important—though often overlooked—roles that soils play as integral, ubiquitous park resources through this brief series of "In Focus" articles.

USDA/SUSAN SOUTHARD

Figure 2. Soils at Mount Rainer National Park preserve a geologic history of past volcanic eruptions.

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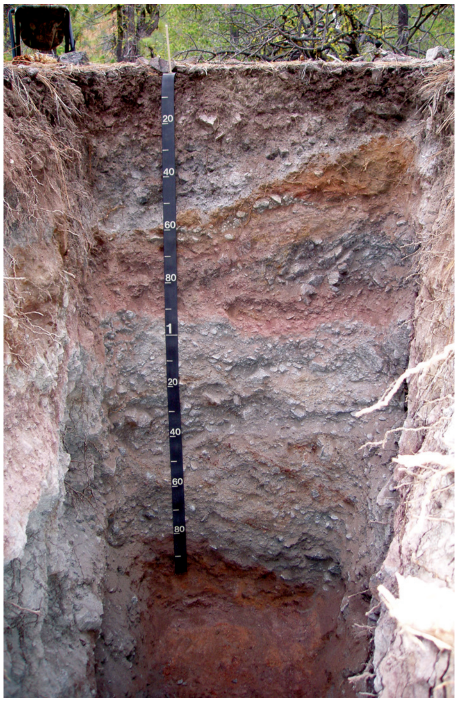

Figure 3. Soil horizons developed in chaotic, tilted landslide deposits associated with an earthquake and subsequent landslide at Lassen Volcanic National Park.

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Figure 4 (top). Sod houses celebrated at Homestead National Monument of America were built from the Kennebec soil, which has the highest soil organic carbon content of any Mollisol in the National Park System. The dense grass roots, which incorporate and sequester organic carbon at depth in the soil, held sod bricks together as homesteaders cut them from the native prairie for building their historical sod homes. Based on Natural Resources Conservation Service certified soil survey data, Kennebec soil has 55 to 65 kilograms (121–143 lb) of soil organic carbon computed on a whole soil basis to 2 meters (6.6 ft). Using a conversion of 4.4515 to change kg/m^2 to tons/acre, the Kennebec sequesters 265 tons of carbon (C) per acre. Assuming a total of 6,000 board feet in a 2,000-square-foot house and 1 pound of C per board foot, the wood framing of a house contains 3 tons of C. Thus, 1 acre of Kennebec soil at Homestead has a C content equivalent to that in 88 single-family homes.

Figure 5 (above, at bottom). Soils are part of building materials, including adobe bricks such as these at Tumacacori National Historical Park. Cultural resource and historic preservation specialists work very hard to preserve these resources. In addition to sod houses (fig. 4, top) other examples of soil-based building materials include mortar and "daub" used to fill cracks between rocks and logs.

Soil and parks

Most people know soil[1] for its agronomic qualities—that our food grows in it. But soils are intrinsic to how we experience and interact with our national parks. Soils are underfoot when we hike a trail, pitch a tent, or stop at a scenic overlook. They support vegetation, terrestrial food webs, and park roads. Through their diversity and variability, soils help define the very character of the parks and their stories, which brings special meaning to these places.

Soils provide unique assemblages of nutrients via mineral and rock weathering that supports ecological niches. For example, at Golden Gate National Recreation Area and Point Reyes National Seashore in California, soils formed on old hydrothermally altered seafloor deposits that have a relatively low calcium and high magnesium content. Only plants that can adapt to these growth-limiting conditions are able to survive in these soils. Some of the rare and endangered plants thriving on these soils derived from serpentinite are Presidio clarkia (*Clarkia franciscana*), San Francisco wallflower (*Erysimum franciscanum*), Raven's manzanita (*Arctostaphylos hookerii* ssp. *ravenii*), and Franciscan thistle (*Cirsium andrewsii*).

Trees of the Pacific Northwest in Mount Rainier, North Cascades, and Lassen Volcanic National Parks thrive on the unique chemistry and physical properties of soils formed from volcanic ash (figs. 2 and 3). Ash parent material often weathers to form noncrystalline particles of aluminum and silica that have high capacity for storing and exchanging calcium, magnesium, and other cations that are important nutrients for plant growth. In contrast, plant

[1]The National Park Service defines soil as "the unconsolidated portion of the earth's crust modified through physical, chemical, and biotic processes into a medium capable of supporting plant growth" (NPS 2014).

communities in the southwestern desert parks are adapted to living in harsh conditions with soils that have a high carbonate content and high salinity.

Human history and culture are also entwined with soils. In Dinosaur (Utah and Colorado) and Bandelier (New Mexico) National Monuments, for example, they provided paint and dyes for pottery and petroglyphs. They were used as building materials for sod houses at Homestead National Monument of America (Nebraska; fig. 4, previous page), prehistoric homes at Wupatki and Walnut Canyon National Monuments (Arizona), and pit house daub at Shiloh National Military Park (Tennessee and Mississippi). Soils are the adobe at John Muir (California) and Bent's Old Fort (Colorado) National Historic Sites, and Tumacacori National Historical Park (Arizona; fig. 5, previous page). They constitute the earthworks at Gettysburg National Military Park (Pennsylvania), Morristown (New Jersey), Valley Forge (Pennsylvania), and Hopewell Culture (Ohio) National Historical Parks; Effigy Mounds National Monument (Iowa); and other parks (figs. 6 and 7).

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Figure 6. The earthen ramparts at Fort Necessity National Battlefield (Pennsylvania) were dug into a hydric soil and failed to keep George Washington's ammunition dry.

NPS PHOTO

Figure 7. Many American Indian cultures built mounds out of soil such as the earth lodge at Ocmulgee National Monument (Georgia).

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Figure 8. Many cultural resources, such as these meditation gardens at Manzanar National Historic Site (California), were built out of soils that need protection.

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Figure 9. Artificial water releases from diversion dams upslope of Manzanar are eroding park lands and cultural resources such as the "hospital garden."

Soils figured in human stories memorialized at some parks. For example, Japanese-Americans who were interned at Manzanar National Historic Site (California) suffered from the high wind erodibility of the soils blowing off the granitic fans of the eastern Sierra Nevada and the relentless fugitive dust of Owen's Lake to the south (fig. 8). Today Manzanar is subject to water releases from diversion dams onto low-cohesion soils formed in granite that result in erosion of cultural resources (fig. 9). The failure of the South Fork dam in 1889, which is remembered at Johnstown Flood National Memorial (Pennsylvania), may have been due in part to high silt content of the soils formed in shale that was used to construct the earthen dam.

Because they preserve events of the past, soils provide strong clues to the geologic processes that formed the landscape. For example, the layering of tephra (soils formed from volcanic ash) and glacial deposition in North Cascades (Washington), Mount Rainier (Washington), Denali (Alaska), and Lassen Volcanic (California) National Parks can both be observed in soil profiles. Continental-scale glacier margins from the last ice age are reflected in the soils of Voyageurs National Park (Minnesota), Delaware Water Gap National Recreation Area (Pennsylvania and New Jersey), and Pictured Rocks National Lakeshore (Michigan). Paleosols (fossil soils) preserve a history of paleoclimates in tectonically uplifted marine deposits on the California coast, including sites at Cabrillo National Monument and Golden Gate National Recreation Area (fig. 10). The Big River soil mapped in Redwood National Park may preserve a record of past tsunamis.

Anthropogenic soils such as fill areas in Golden Gate NRA (California) and Gateway NRA (New York and New Jersey) serve as examples where human-modified soils have been identified and classified and are included in the NPS Soil Resource Inventory (fig. 11). These soils preserve important histories of why and how humans have altered their natural environment.

How do park environments play such fundamental roles in defining the character of our soils? It is diversity and combinations of physical, chemical, and biological characteristics and how these factors interact that distinguish soils (fig. 12). A five-part

Evidence of past climates can be observed in paleosols.

USDA/SUSAN SOUTHARD

Figure 10. Fossil soils, called paleosols, at Cabrillo National Monument record stories of the past. They formed in marine deposits that were tectonically uplifted during times when climatic conditions were warmer and wetter than those of today.

USDA/SUSAN SOUTHARD

Figure 11. The parade grounds at Fort Baker in Golden Gate National Recreation Area are formed on artificial fill, called a Xerorthent by soil scientists. The fill is derived from dredged material and can be susceptible to subsidence (settling) during earthquakes.

USDA/CHARLES DELP

Figure 12. Three distinct soil horizons, comprising dark-colored organic matter at the surface, white-colored leaching organic matter and clay in the middle, and black and orange–colored translocation of the organic matter and clay to the subsoil, are visible in this shallow soil pit dug by scientists in sandy river soils at Gauley River National Recreation Area, West Virginia. These soils, which scientists classify as Spodosols, tend to have low nutrient content because of leaching.

model helps scientists classify soils by discerning their properties based on the interaction of water and (1) parent material (rocky type), (2) organisms (including people), (3) time (often measured geologically), (4) climate, and (5) topography. Soil surveys have been conducted over the past 20 years through the NPS Natural Resource Stewardship and Science Inventory and Monitoring Program in partnership with the National Cooperative Soil Survey Program led by the USDA Natural Resources Conservation Service. This effort has provided basic information on soil types and their distribution in more than 270 national parks. The soils data and information are constantly being refined and updated, providing parks with important data sets that relate to the management of park natural and cultural resources, facilities, and operations.

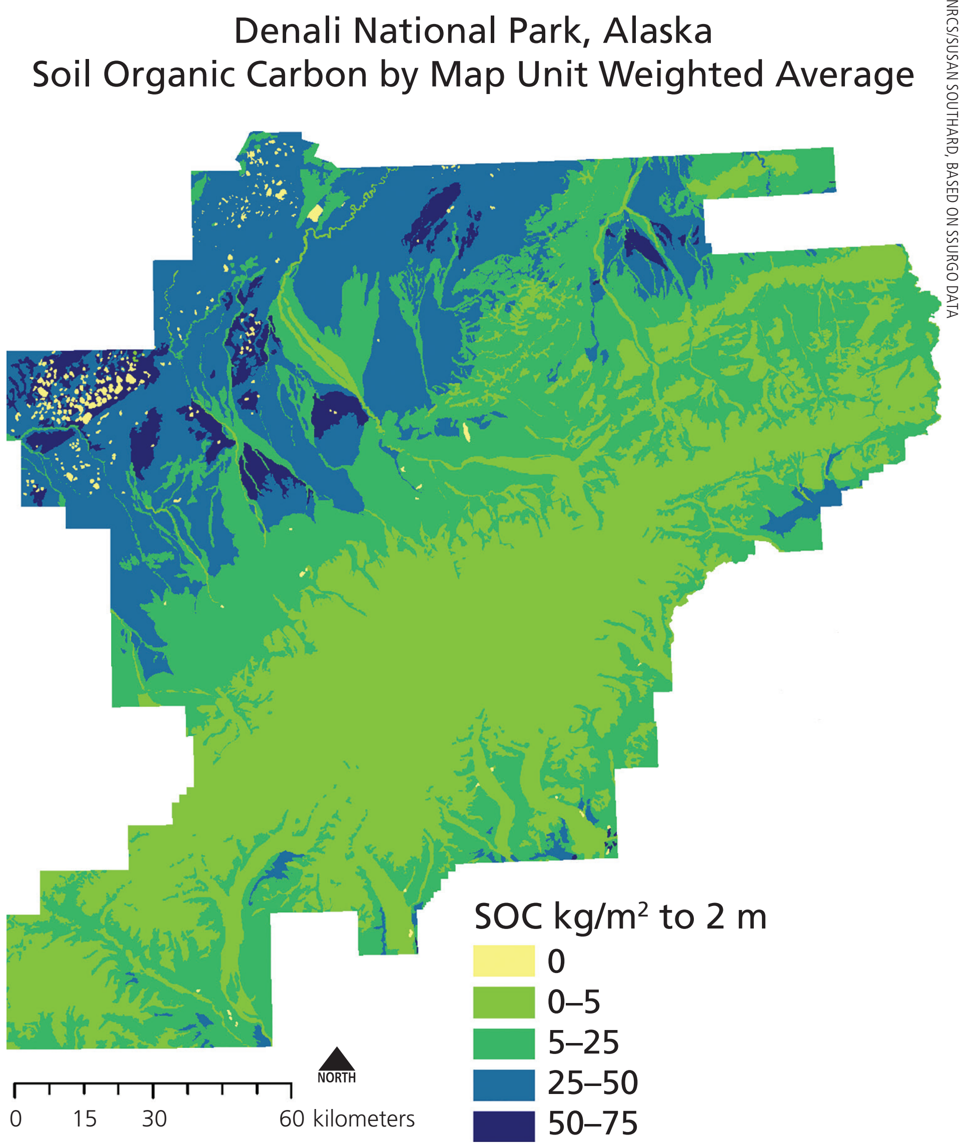

Figure 13. Soil organic carbon stocks of parks are easily obtained by using certified soils data, such as provided by this soil carbon map of Denali National Park and Preserve.

Three emerging issues

Just as it prescribes management guidelines for species and other park resources and values, *NPS Management Policies 2006* (NPS 2006, section 4.8.2.4) directs the National Park Service to conserve soils. An important component of this policy is the use of science to inform our understanding of soil formation processes, soil properties and behavior, and what activities are detrimental to soils. This information helps us determine best management practices.

Three contemporary management issues relate to soils in the following ways:

Carbon sequestration

Decomposing plants and animals contribute organic matter to soils, including organic carbon, nitrogen, and other plant nutrients. This soil organic matter is about half organic carbon and increases pore space and other soil properties, such as water-holding capacity, that are essential for plant growth. Microbial degradation of soil organic matter can either make nutrients available to plants or transform them to make uptake by plants difficult; in either case these processes create reserves of organic carbon in soil, resulting in soil carbon sequestration.

Soil is the largest terrestrial carbon sink on Earth, and parks contribute to the carbon sequestration process through their protected status. Carbon bound in soil buffers ecosystems against the effects of global climate change and is sustained in part through good park management. The aforementioned soil surveys provide a way to account for soil carbon and have been used to highlight park soil carbon stocks (fig. 13). The role of soils in carbon sequestration on park lands will become increasingly important as we seek to understand and adapt to the impacts of climate change on park resources and processes.

Biodiversity

Soils host one-fourth of the world's biodiversity in bacteria, fungi, and invertebrates (fig. 14). They provide a critical habitat for plants (roots) and burrowing

NPS/ART COHEN

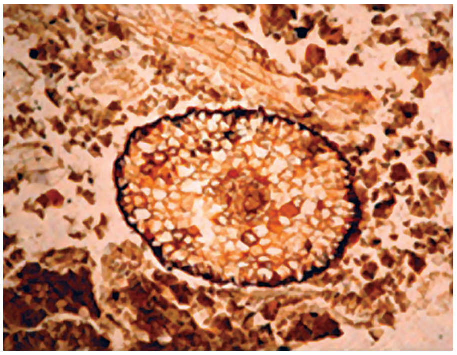

Figure 14. Microscopic analysis of organic-rich soils at Congaree National Park shows evidence of plant roots, insect burrows, fungal spores, charcoal, pollen, and other life-forms that have accumulated on the forest floor since the last ice age.

animals such as snakes, armadillos, prairie dogs, ground squirrels, gophers, moles, and burrowing owls. They also contain a broad range of climatic and chemical environments. Though taxonomists have only scratched the surface of inventorying the myriad species found in soils, biodiversity will surely increase significantly as these lesser-known soil microhabitats are explored. Similarly, although bioblitzes conducted broadly in national parks have added to our knowledge and understanding of life in these places, there have been few attempts to paint a picture of life belowground. Nevertheless, scientists can provide impressive estimates for soil organisms. These estimates range from 9,000 species of bacteria and Archaea per cubic centimeter (549/cu in), 100 genera of nematodes per square meter (131/cu yd), and more than 100 species of mites per square meter (131/cu yd) (Bardgett and van der Putten 2014). Altogether these species provide for a number of beneficial processes and services.

Ecosystem services

Soils play many important roles in ecosystems. By providing physical media and supplying water and nutrients for plants and animals, soils support the very basis of all food webs and park species. Soils store, filter, and purify water; regulate water flow; control erosion; mitigate flooding; and cycle plant nutrients such as nitrogen, all of which are important services that help sustain landscapes across the National Park System. Outside of parks, soils are involved in the production of hundreds of everyday products that benefit humans, including clay, sand, and gravel in the construction of road beds, and raw materials used to manufacture insulation and filters. Microbes gathered from soils are used in the production of antibiotics (Ness 2015), and earthworms are important as fish bait. Soils even exert controls over pests and diseases through properties such as ionic strength and pH, and soluble organic carbon content (Comerford et al. 2013).

Soil science

Soils are ubiquitous in national parks and in our lives, and our efforts to understand how they behave and interact with their environments are critical. So to round out our primer the following two articles highlight important advances in resource science and management related to soils. In addition to their specific areas of focus, these investigations improve our understanding of how, through dynamic and static processes, soils are linked to numerous other resources and activities in parks and in the broader landscapes beyond parks. The National Park System includes an amazing array of soil types, functions, and services. By continuing to develop our understanding of them we can celebrate their importance in parks alongside memorials, rivers, and wildlife.

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