THE SOIL'S LIVING SURFACE
Biological Crusts

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Biological crusts are assemblages of microscopic organisms dwelling on the soil surface in arid regions. They are important for retaining water, reducing erosion, cycling nutrients, and diminishing the invasion of exotic plants. Range managers have typically disregarded the ecological role of biological crusts, yet they are easily disturbed and destroyed by livestock, and recovery can take years.

The plants most people think of as characteristic of the arid West are the large, vascular types, such as various grasses, sagebrush, rabbitbrush, bitterbrush, cacti, and juniper. Few people are aware of one of the most important groups of plants found on arid lands: biological soil crusts. These are assemblages of tiny, often microscopic organisms, such as cyanobacteria, green algae, fungi, lichens, and mosses, living on or just beneath the soil surface in the spaces between the larger, more prominent vegetation. Although inconspicuous, biological crusts are critical to the productivity of many arid land ecosystems and in some places account for 70 percent of the living plant cover on soils.[1]

Unfortunately, the important role of biological crusts has been unnoticed or ignored by many people, including most range managers and livestock grazing proponents. Traditionally, only the impact of livestock grazing on vascular plants has been a concern in evaluations of rangeland health. Yet recent research suggests that even if vascular plant communities are not affected in any detectable way by livestock, there can be significant differences between grazed and ungrazed sites in the proportion of ground covered by biological crust.[2] And over time, livestock damage to biological crusts can lead to the declining health of the entire ecological system—from increased soil erosion, diminished water-holding capacity of the soil, and less favorable nutrient flows, to greater vulnerability to invasion by exotic plants.

Biological Crusts as Part of Arid Ecosystems

Biological crusts, perhaps in keeping with their rather hidden nature, are known by many terms, such as *microbiotic crusts*, *cryptogamic crusts*, and *cryptobiotic crusts*. They are particularly important components of arid ecosystems, such as those in the Great Basin, the Colorado Plateau, and the deserts of the Southwest, although they can be found in rangeland ecosystems from alpine areas to the Great Plains. Biological crusts are native elements of most western public lands.[3] As a group they are amazingly diverse and often account for a far greater number of species than the vascular plants with which they are associated.[4] For example, in southern Idaho, botanist Roger Rosentreter found 16 vascular plant species and 39 biological soil crust species in 140 plots placed throughout the rangeland plant community.[5]

Biological crusts help to hold the soil surface together and thus reduce soil erosion from wind and water.[6] They play an important role in reducing the impact of raindrops; on unprotected soils (lacking biological crusts), heavy rain breaks up soil aggregates, which leads to the clogging of soil pores and reduces water infiltration rates, sometimes as much as 90 percent.

The crusts also create small-scale roughness or depressions in the surface of the soil that catch water, allowing it to infiltrate, thus reducing sheet erosion.[7] Some biological crusts have microfilaments that weave soil particles together,[8] again anchoring the soil against erosion. Biological soil crusts also act as mulch, reducing evaporative water losses.

Some biological crusts capture and fix atmospheric nitrogen,[9] and all of them can contribute to carbon fixation,[10] providing an important source of carbon for microbial soil populations. Since nitrogen and carbon are both limiting factors in arid environments, maintaining normal nitrogen cycles and carbon deposition is critical to soil fertility and prevention of desertification.[11] Vascular plants growing in soils with intact biological crusts have been found to have a higher concentration of nitrogen than plants growing in soils lacking such crusts.[12]

By occupying the spaces between perennial plants, biological crusts also prevent the establishment and spread of exotic weeds. Most native perennials found in North American deserts tend to have seeds with self-burial mechanisms or that are cached by rodents—ensuring that they will be covered by soil or plant litter and will be able to germinate. However, the seeds of most exotic species, such as cheatgrass, do not use these strategies; rather, they germinate on the soil surface. Where biological crusts are intact, seeds of exotics

Area surrounded by livestock-inaccessible cliffs, Arch Canyon, Bureau of Land Management lands, Utah. A biological crust covers the soil surface on this desert site. These crusts are critical to the conservation and productivity of arid land soils. They hold the soil together, reduce water evaporation rates from the soil, and add nitrogen to the soil. They make it more difficult for weeds and exotic plants to become established. However, biological crusts are easily destroyed by trampling. Livestock are the major culprits in the decline of biological crusts throughout the West.

generally fail to germinate successfully. Indeed, the loss of crusts in the bunchgrass communities of the Intermountain West may be largely responsible for the widespread establishment of cheatgrass and other exotic annuals.[13]

Another unexpected positive aspect of intact biological crusts is their role in creating favorable microclimates. Most biological crusts are dark and can raise temperatures as much as 23 degrees Fahrenheit above that of adjacent surfaces.[14] Heightening soil temperatures can increase nutrient uptake and speed seed germination, photosynthetic rates, and nitrogenase activity for associated vascular plants. Ants, arthropods, reptiles, and small mammals are able to forage more effectively and more quickly with warmer soil temperatures, because they themselves are then warmer and more active.[15]

Higher temperatures may be critical in many desert environments since soil moisture is typically higher during the cooler fall, winter, and spring months, and biological activity may be dependent on favorable soil temperature and moisture. When the dark-colored biological soil crusts are eliminated, the result can be lowered biological activity, with green-up pushed back to later in the spring and early summer. This can negatively affect vascular plants, since they are usually limited by soil moisture, and soils generally dry out as the season progresses into the warmer months.

Finally, biological crusts play a role in moderating fire frequency and intensity. Native plants in the most arid parts of the West are naturally widely spaced, and fires usually do not carry far because of the discontinuous and patchy distribution of fuels. Biological crusts occupy the open spaces between the larger plants—impeding the establishment of exotics, such as cheatgrass, which allow fires to carry farther and also increase fire frequency. So long as the crusts help maintain these mini firebreaks, fires are slowed, and their intensity is decreased.[16] Furthermore, under low-intensity blazes, soil crusts remain intact, limiting potential erosion that may occur in the aftermath of a fire.[17]

Effects of Livestock Production

Various human activities can damage biological crusts, including use of off-road vehicles and even hiking. However, no human activity is as ubiquitous on western public lands as livestock grazing.

Livestock damage biological crusts primarily by trampling them. Except perhaps at the lightest stocking rates, the presence of livestock results in broken, degraded crusts. Livestock also tend to compact soils by walking on them repeatedly. Compaction can lead to changes in soil moisture and nutrient flow, which in turn can alter the species makeup of crusts. These changes may occur before differences in biological crust cover are apparent at the macroscopic level.[18]

Biological crusts need moisture for growth and reproduction. Livestock grazing in the spring, just prior to the beginning of hot, dry periods, limits opportunity for regrowth of crusts. The net effect of the loss of biological crusts is magnified in areas where high-intensity summer thunderstorms occur; heavy rains on unprotected soil surfaces lead to significant erosion.[19] Livestock grazing in summer and fall is also detrimental since biological crusts are particularly susceptible to breakage and fragmentation when dry.[20] Spring, summer, and fall are the primary seasons for livestock grazing on public lands.

Full recovery of badly trampled biological crusts typically requires more than a few years. Since most public rangelands are not allowed more than a season or two of rest, even under the best rest-rotation management plans, complete recovery is essentially precluded under any livestock grazing regime.[21] It is important to understand that biological crusts occur most prominently in ecosystems that did not evolve with large herds of grazing ungulates. Along with the grasses native to such areas as the Great Basin, the Colorado Plateau, and the Mojave, Chihuahuan, and Sonoran Deserts,[22] the biological crusts lack adaptations to the frequent presence of big-bodied herbivores. This fact helps explain why crusts are so vulnerable to damage in the face of livestock grazing.

The negative effects of livestock on biological crusts contribute to lower productivity, accelerated invasion of exotics—particularly cheatgrass—changes in fire regime, changes in soil structure, reduction in water infiltration, higher soil erosion from wind and rain, and changes in energy pathways. These impacts are nearly unavoidable when livestock are present, and thus the policy of allowing livestock grazing on public lands is in direct conflict with such goals as maintaining healthy ecosystems and limiting the occurrence of costly and ecologically damaging cheatgrass-fueled fires.

Bunchgrasses in Wupatki National Monument, Arizona. No livestock are allowed here.