Monitoring Rangeland Health: Using a Biological Soil Crust Stability Index

Roger Rosentreter
David J. Eldridge

Abstract: Monitoring of rangeland health has recently transitioned from the taking of simple grass biomass measurements to a more integrated plant biodiversity and soil surface condition evaluation. One component being measured is the composition and cover of biological soil crusts (bsc). The bsc cover has been shown to correlate with soil stability. The bsc index is conducted in arid lands with clumped vegetation along a 20-m line intercept. The bsc stability index stratifies the bsc into one or more of three morphological categories, records that category by cover class, and then calculates a quantitative index. The bsc index is measured only in the plant interspaces. This index allows for comparison with other sites and for trend evaluation at the specific site over time. This bsc index readily rates the stability of the plant interspace soil and requires little analysis time or delay.

Keywords: monitoring, crusts, lichens, health, rangelands

Background

Biological soil crusts are integral components of rangeland soils on many continents. These complex assemblages of lichens, liverworts, mosses, cyanobacteria, and algae dominate the first few millimeters of the soil surface. Because of their close association with surface soils, crusts play an important role in the regulation of water, sediment, and nutrient flows, and provide favorable sites for the germination and establishment of some rangeland plants (Eldridge and Rosentreter 1999; West 1990).

Biological soil crusts are generally regarded as indicative of healthy landscapes due to the resistance they impart to the soil surface against wind and water erosion. Despite this, however, nonvascular plants have rarely been included in broad-scale inventories or assessments of rangeland health (West 1990). Biological soil crust organisms have traditionally been very difficult to identify, even to genus or family level, because of their small size, lack of definitive morphological features, and the fact that some species are separated on the basis of their chemistry.

Techniques that use biological soil crusts to assess soil health were pioneered in the semiarid woodlands of Eastern Australia in the early 1980s (Tongway and Smith 1989). Biological soil crust cover, along with other soil surface features, provides an indication of the extent to which the soil cycles nutrients, accepts rainfall, and resists erosion (Tongway and Smith 1989). Despite the incorporation of biological soil crusts into rangeland health assessment, there has been a reluctance to use crusts as indicators due to the problems discussed above. Eldridge and Rosentreter (1999) proposed crust monitoring at the level of morphological groups, rather than using a species-based approach. Morphological groups can be useful indicators of soil surface stability due to the strong association between morphology and function. This association provides an indication of the degree to which single or groups of organisms can resist perturbation.

Landscapes where the soil surface supports an extensive cover of biological soil crusts are known to be relatively resistant to wind and water erosion. Erosion, by removing part of the soil surface horizon, is an indicator of a rangeland's declining health (Davenport and others 1998; Dormaar and Willms 1998). Erosion reduces the productive potential of the soil by decreasing soil organic matter, cation exchange capacity and hence structural stability, and by reducing the capacity of the soil to accept infiltration. Ultimately, depauperate soils have lower infiltration rates and excessive overland flow, thereby reducing their structural stability and production capacity.

Soil Crust Index

A Biological Soil Crust Stability Index (BSCSI) integrating the surface cover of biological soil crusts with their ability to protect the soil against erosion has been developed for patterned grasslands and shrublands where cryptogamic crusts are a major component of the interspace soil matrix. This index ranks morphological groups of cryptogamic taxa in terms of their increasing dimensionality and hence their resistance to erosion. This is a practical system of monitoring that simplifies and unifies previous methods in order to encourage wider use and application. Even morphological groups are sometimes difficult for observers to determine during field survey. The soil crust index system

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Roger Rosentreter is Botanist, U.S. Department of the Interior, Bureau of Land Management, 1387 S. Vinnell Way, Boise, ID 83709, U.S.A. E-mail: roger_rosentreter@blm.gov. David J. Eldridge is Senior Research Scientist, Department of Sustainable Natural Resources, School of Biological, Earth and Environmental Sciences, University of NSW, Sydney, 2052, NSW, Australia; e-mail: deldridge@unsw.edu.au

simplifies taxa even further according to their dimensionality, characterizing cyanobacteria and algae as one dimensional; crustose, squamulose and foliose lichens and liverworts as two dimensional; and fruticose lichens and mosses as three dimensional.

Increasing dimensionality is considered indicative of greater erosion control and increasing rangeland health. One-dimensional soil crusts occur within the soil matrix and may be difficult to see, but they resist raindrop impact and hold the soil together, therefore protecting it from surface waterflow and wind erosion. Their impact is most marked on sandy soils where they often provide the only biological soil protection. Two-dimensional soil crusts are similar in their protection from erosion, but because they are generally larger and grow on top of as well as within the soil, they provide greater protection from raindrop impact, and the small cracks between crust organisms may act as traps for wind- and water-borne sediment. Three-dimensional soil crusts are generally larger than two-dimensional crusts, and their three-dimensional structure can capture and accumulate windblown dust and nutrients more effectively than two-dimensional crust types.

In patterned vegetation communities in Idaho, U.S.A., and western NSW, Australia, a 20-m line-intercept method has been used to determine the BSCSI. These measurements are often made in conjunction with other assessments of rangeland health, which involve measurements of the size and arrangement of vegetation patches.

The proportion of the various dimension types is multiplied by a rating value, which reflects the relative value of the crust type to resist erosion, or deformation. Research is currently underway to refine these stability ratings for various dimensional types. For example, we are subjecting the three crust types (1-D, 2-D, 3-D) to a range of laboratory tests to examine their ability to resist stress (Emerson aggregate test, water drop test), trap sediment (laboratory simulations of microwind erosion), retain water (immersion and drying tests), and withstand deformation (consistency and coherency tests). Empirical data from these laboratory tests will be subjected to multivariate analyses to determine overall relative differences in effectiveness of the three-dimensional types at stabilizing the soil surface. Preliminary results suggest that the 3-D surfaces are about 10 to 15 times more effective than 2-D surfaces, which are about 3 to 5 times more effective than 1-D surfaces (table 1).

Table 1—Dimensionality of biological soil crusts in relation to morphological group and stability rating.

Crust dimenstion type	Morphological groups	Stability rating value
1-D	Cyanobacteria, fungi, and algae	1
2-D	Crustose, squamulose and foliose lichens, and liverworts	3 to 5
3-D	Tall and short mosses, fructicose lichens	10 to 15

An overall rating for a site is calculated by multiplying the stability rating value for each crust type in each interspace by a value that reflects its cover, and expressing that number as a percentage out of 60, the maximum possible score. This has the effect of relativizing sites and therefore enables comparison between sites. The system is still under refinement and has yet to be tested in other environments.

Discussion

Although this system is still being tested and revised, it appears to be of value regardless of the vegetation type as long as the native vegetation is clumped or patterned (Rosentreter and Eldridge 2002). Results to date have shown strong relationships between the index and an independent assessment of health of the rangelands (fig. 1). The Biological Soil Crust Stability Index may underestimate crust contribution to total soil stability. However, this is a good system for comparing sites over time in a relative sense. The Index provides a rapid method of assessing the structure and condition of interspaces in shrublands and grasslands. This system should prove a useful tool for monitoring temporal and spatial changes in soil crust communities in patchy environments.

The Biological Soil Crust Stability Index is an efficient method because it requires less training, provides rapid and statistically powerful data analyses, and allows for rapid field measurements. Trampling impacts to the vegetation and cryptogamic crusts are focused in the interspaces of patterned arid vegetation. Therefore, impacts and changes in range condition are first measurable in the interspaces between plant clumps.

This Index evaluates microphytic vegetation and its impact without losing the small-scale structural features that influence hydrologic and watershed stability. This system is proposed as a rapid and efficient technique for monitoring

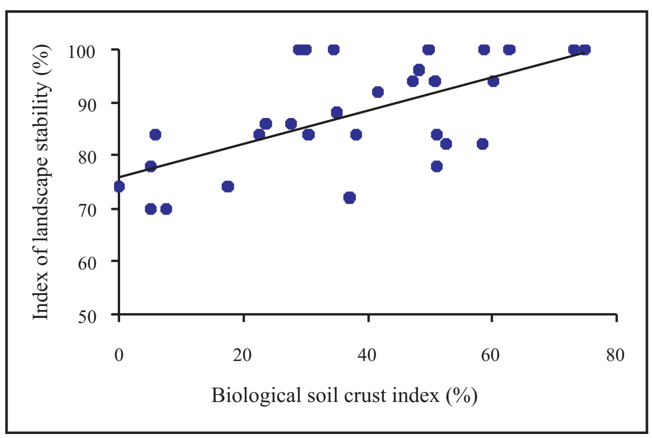

Figure 1—The relationship between the Biological Soil Crust Stability Index (BSCSI) and an index of landscape stability for *Artemisia* shrublands in Idaho.

erosion hazard potential, temporal and spatial changes in the quality of plant and animal habitat, and wildfire risk.

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