Biotic and abiotic characteristics interact with fire history to influence biological soil crust cover and composition in the Columbia Basin

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Introduction

Biological Soil Crusts (BSC) in cool deserts are dominated by lichens and that live on the soil surface.

BSCs provide several functions, including soil stabilization and aggregation, photosynthetic activity, nutrient input to the soil, and may aid in plant seedling establishment[1].

Distribution of BSC is patchy across the landscape (Fig. 1) and has been shown to be related to:

- **physical conditions**: heat load, water availability, soil characteristics, and light availability[2], silt and Mn and Zn concentration[3], and pH and calcium carbonate levels[4].
- **biotic conditions**: eg. dominant bunchgrasses[2]. Soil nutrients were higher under plants than in interspaces[3]. Plant litter can shade the surface and prevents photosynthesis.
- **disturbance history**: trampling by animal or vehicle, fire, and pollution can reduce BSC[5]. Components of BSC have varying growth rates, with some mosses able to colonize rapidly but some lichens taking decades to grow.

Fig. 1: Examples of extremes of BSC cover and communities. Left: loamy soils with diverse BSC. Right: sandy soils with moss.

Many factors can interact affecting available substrate space, nutrients, water, light, and time (Fig. 2).

The objective of this study was to determine the factors and interactions affecting moss and lichen cover and composition in shrub steppe with varied fire history

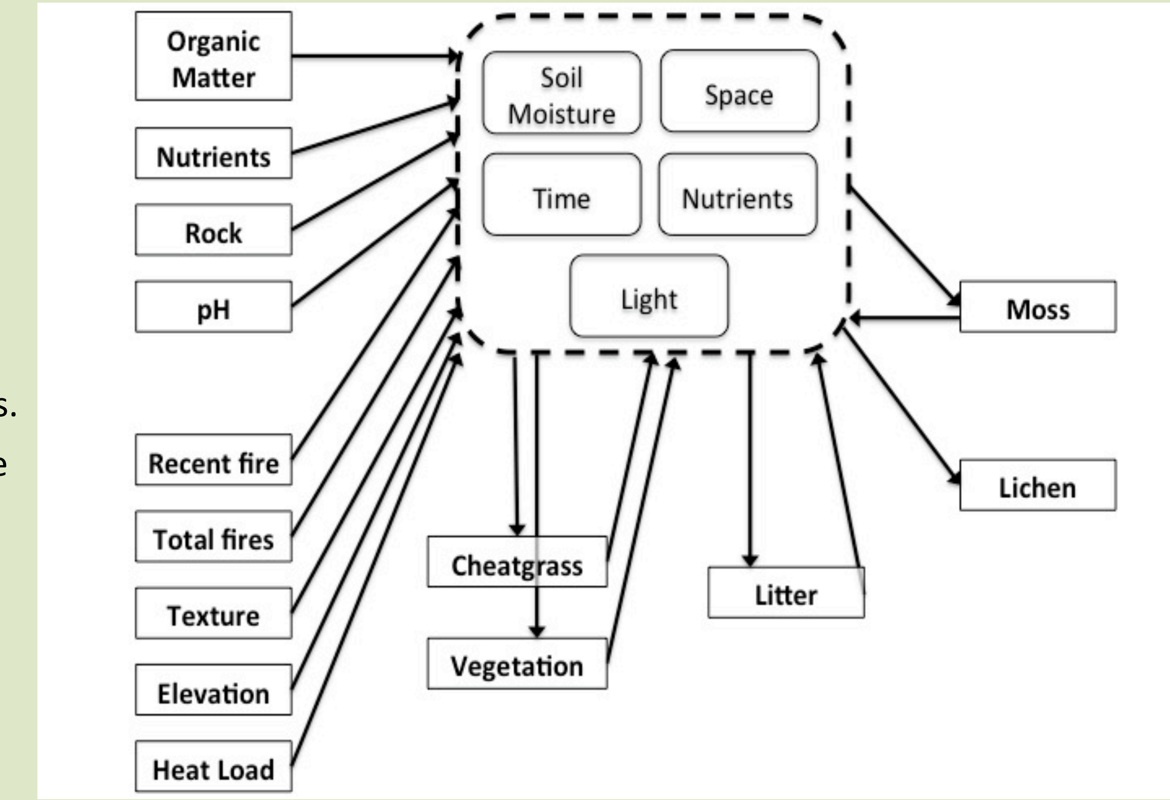


Fig. 2: Conceptual diagram of hypothesized relationships between observed variables (in rectangles) and unobserved variables (in curved boxes). Dotted curved box is in place to reduce complexity of the diagram because arrows from each observed variable can affect more than one unobserved variable. Causal and dependent relationships between cheatgrass, vegetation, litter, and moss and the unobserved variables are indicated, but feedback relationships between observed variables are not modeled.

Methods

Fig. 3: Quadrats and landscape types sampled.
Top left to bottom right: low elevation with little cover, cheatgrass monoculture, bluebunch wheatgrass, lithosol forbs, Carey's balsamroot, Wyoming sagebrush, phlox, bunchgrass and forb community, lithosol and steep slopes.

Data Collection

- 98, 100m transects, each with five 20x50cm quadrats, across Benton County, WA with varied topography, soils, vegetation, and fire history (Fig. 3).
- B, Mn, Zn, Al, P, Ca, Mg, Na (first axis of Principal Components Analysis), percent organic matter, pH, and texture (sum of percent clay and silt components).
- Heat Load Index, elevation, recent fire (number of years since fire) and total number of fires.
- Total Cheatgrass, vegetation, litter, rock, moss, and lichen cover recorded to nearest 1% *(Quadrats with rock cover greater than 20% were excluded)*
- Frequency of occurrence per transect of each moss, lichen, and plant species was used for composition.

Statistical Methods

- Structural Equation Modeling (SEM) uses multiple structural equations to model multivariate relationships of simultaneous influences and responses[6]. *A priori* relationships represented in Fig. 4.
- Mantel test for spatial autocorrelation.
- Procrustes Analysis tests the non-randomness between the vegetation community and BSC community.
- Permutational ANOVA to test for significance of factors that remained in the SEM model.
- Nonmetric Multidimensional Scaling to view ordinations

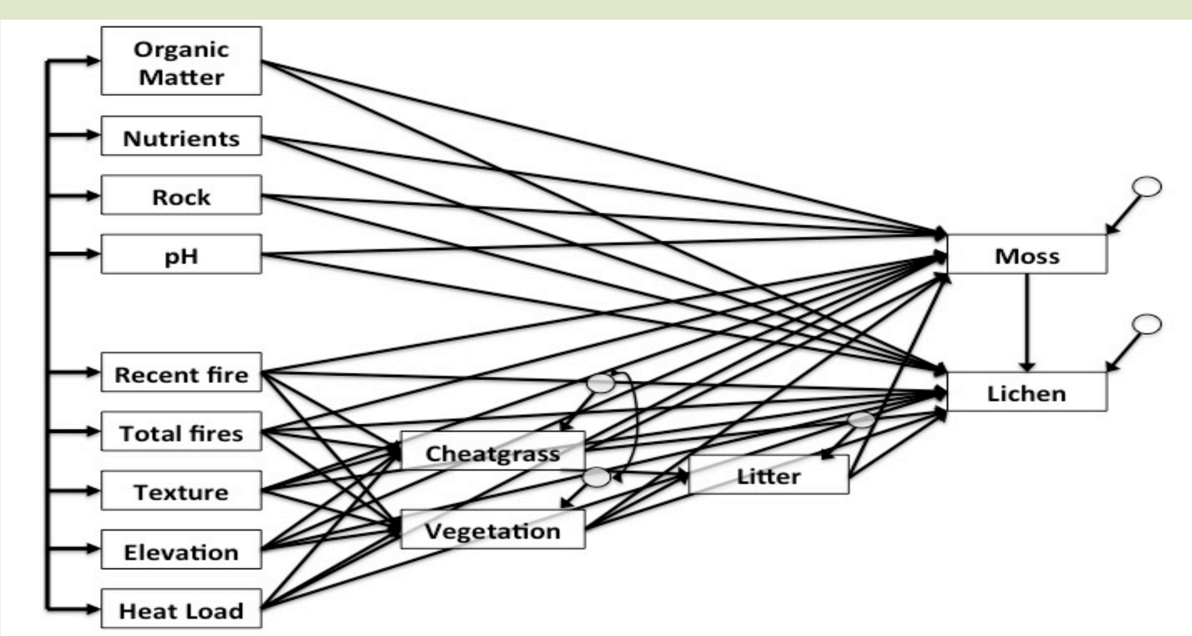


Fig. 4: Proposed pathways from abiotic, disturbance, and biotic pathways to biological soil crust cover. Arrows to empty circles denote error terms. The arrows connected by a vertical line is a simplified way of portraying correlations between all exogenous variables. The double-headed curved arrow indicates unresolved correlation between the errors of Cheatgrass and Vegetation. Single headed arrows indicate proposed causal relationships between variables. All response variables were natural log transformed.

Results for total BSC cover

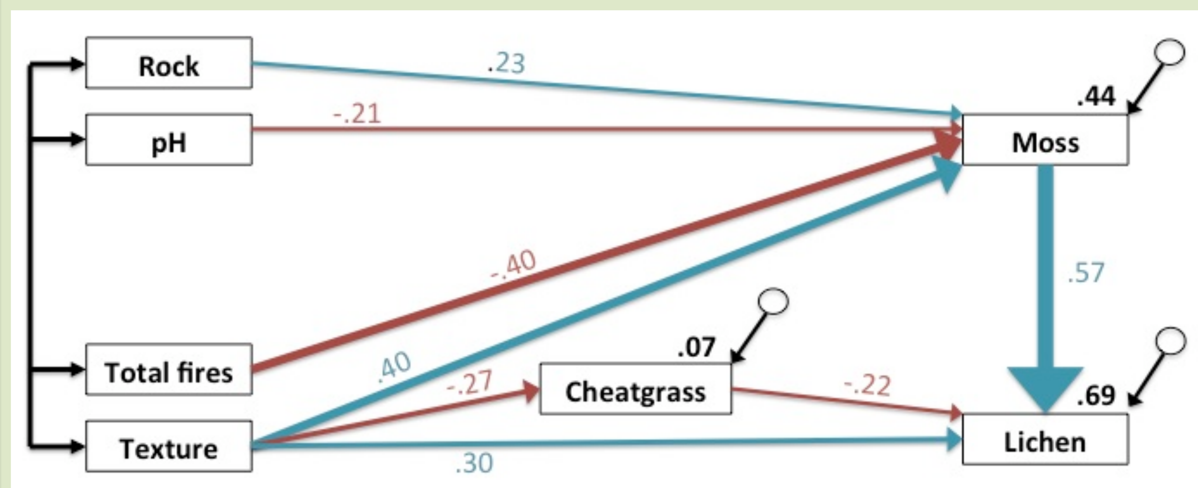


Fig. 5: Final SEM path diagram. Chi square = 6.805, p =0.449 (the non-significant value indicates that the structure of the data is not significantly different than predicted by the model). Red = negative interaction. Blue = positive interaction.

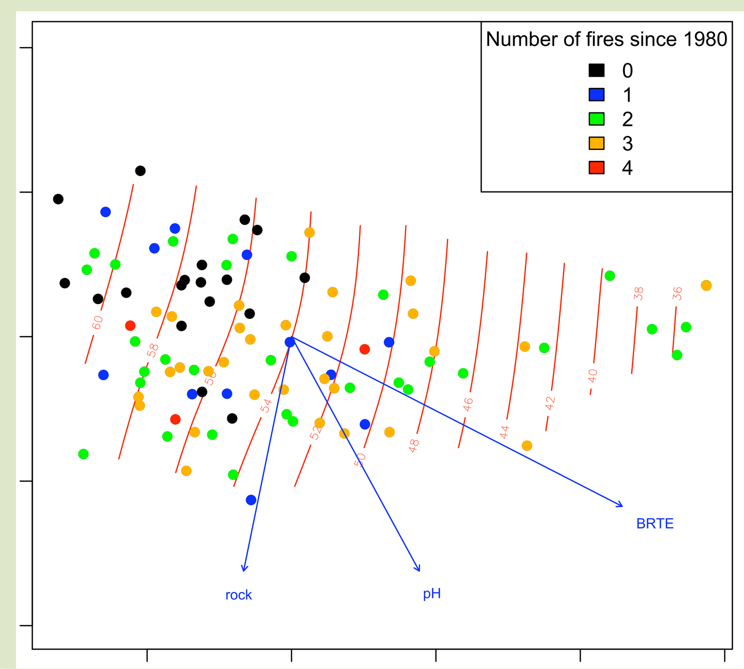
- Moss cover is most strongly related to the direct relationships between total fires and texture with weaker significant factors of rock cover and soil pH (Fig. 5)
- Lichen cover is strongly associated with moss cover, with weaker direct and indirect effects of cheatgrass and soil texture (Fig. 5, table 1)

Table 1: Standardized total effects of explanatory factors on responses

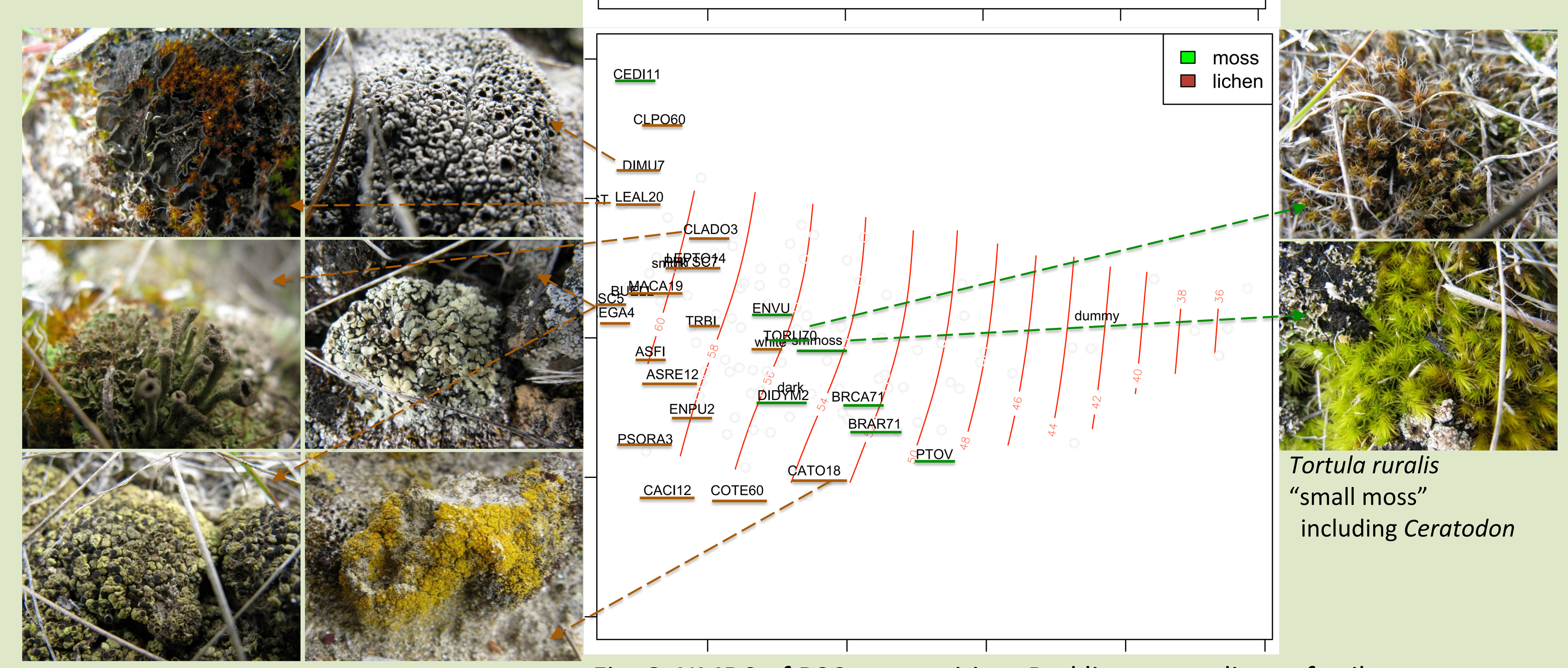
	Texture	Total	pH	Rock	Moss	Cheatgrass
Moss	0.39	-0.40	-0.21	0.23		0
Cheatgrass	-0.27	0				
Lichen	0.59	-0.22	-0.12	0.13	0.57	-0.22

Results for BSC composition

- There was no strong grouping of plots associated with number of fires (Fig. 6, top). Sites with no fires were generally more similar than plots that had been burned. In fine soil textures, there were many burned plots that were similar to unburned plots.
- Total fire, cheatgrass cover, pH, rock cover, and texture were all significantly related to crust community (p < 0.0001).
- Sites closer together were more similar in composition than plots farther away (Mantel r: 0.1844, p < 0.001).



- Unburned plots generally associated with foliose or fruiticose lichens (Fig. 6, bottom), while burned plots with crustose lichens and mosses. Plots with no species ("dummy") were associated with high cheatgrass cover and coarse soil texture.
- Vegetation community composition explained 52% of variation in BSC community composition (Procrustes, p < 0.0001).



Leptochidium albociliatum
Cladonia sp.
Acarospora schleisherii

Diploschistes muscorum
Leptogium cf *garovaglii*
Caloplaca tomenii

Tortula ruralis
"small moss" including *Ceratodon*

Fig. 6: NMDS of BSC composition. Red lines = gradient of soil texture.
Top: Plots coded by number of fires and fitted univariate factors (BRTE = cheatgrass).
Bottom: Centroids of moss and lichen species (USDA codes)

Conclusions

- Fire history affects both BSC cover and composition. Lack of fire is associated with "late successional" groups such as fruiticose lichens and higher cover of moss. This study supports observations of slow recovery of mature BSC from fire. Severity of fire likely affects BSC but that was not addressed in this study.
- Cheatgrass is negatively related to BSC cover.
- Sites with mature vegetation likely have mature BSC composition also (Fig. 7).
- Rock cover may affect microsite conditions, perhaps providing shade or protection from hoof disturbance.
- pH affects availability of nutrient ions. Species differ in tolerance for soil acidity.

➢ **To protect cover and diversity of biological soil crusts in Columbia Basin, efforts should be made to reduce fire frequency and remove or prevent cheatgrass invasion.**

➢ Other factors affecting BSC can not be manipulated, but can be used to target areas of higher concern. Soil texture affects both crust cover and composition directly, likely by increased moisture retention in finer soils. If priority is to restore crust in degraded areas, coarser soils should be selected, but to protect extant BSC communities, areas with finer soils should be protected from disturbance.

Fig. 7. Other species found include *Trapeliopsis glaucophyllus* (left) and the rare *Taxosporium sancti-jacobi* (right), indicating long disturbance-free periods

Acknowledgements
Jim Grace, Katie Glew, Jeanne Ponzetti, Roger Rosentreter, Heather Root, Terry McIntosh, Heidi Newsome, BLM , and other landowners

References:
1. Bowker, M. A. 2007. Restoration Ecology **15**:13-23.
2. Ponzetti, J. M., B. McCune, and D. A. Pyke. 2007. Bryologist **110**:706-722.
3. Bowker, M. A., J. Belnap, D. W. Davidson, and S. L. Phillips. 2005. Ecological Applications **15**:1941-1951.
4. Eldridge D.J. and M.E.Tozer. 1997. Bryologist 100:28-39
5. Belnap, J. and D. Eldridge 2001. Pages 363-383 in J. Belnap and O.L. Lange, editors, Ecological Studies **150**. Springer and Verlag, Berlin, Germany.
6. Grace, J.B. 2006. Structural Equation Modeling and Natural Systems. Cambridge University Press, Cambridge, UK.