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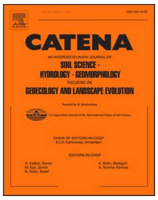

Large scale environmental drivers of biocrust distribution and development across a sandy desert in China

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ABSTRACT

Biological soil crusts (biocrusts) are widely distributed in arid and semiarid ecosystems and provide critical ecological functions. Understanding how biocrusts change across broad regional scales allows us to manage them more effectively under changing climates and land-use pressures. Based on field surveys, we used boosted regression trees and correlation analysis to examine the changes in cover, distribution and developmental characteristics of biocrust mosses and cyanobacteria, and environmental factors at 40 sites in the Mu Us Sandland in northwestern China. We found that higher elevation sites (~1342 m) were the most suitable for biocrust distribution, and preferred sites were characterized by greater vegetation cover (>43%), values of the aridity index (>0.34), slope (>6.6°), soil pH (>8.85) and soil organic carbon (>0.50%). Increasing levels of disturbance (>1.15 kg dung ha^{-1}) suppressed biocrusts. Moss crust development (e.g., biomass, thickness, bulk density) was significantly positively related to vegetation cover, aridity index, and soil organic carbon, and moss crusts tended to prefer shady shrub communities at low elevations. Shady and steep (5 – 15°) slopes and higher soil nutrient contents were positively correlated with cyanobacteria development. Reduced rainfall and increasing disturbance intensity would reduce the distribution and development of biocrusts. Our study provides a basis for informed decision making about how to manage moss and cyanobacterial crusts in the Mu Us Sandland as the region becomes hotter and drier.

1. Introduction

Biological soil crusts (biocrusts), comprising lichens, mosses, fungi, cyanobacteria, and algae, can contribute up to 70% of the living cover in arid and semiarid regions worldwide (Belnap, 2002). Biocrusts fix carbon and nitrogen (Belnap, 2002), help the soil to resist water and wind erosion (Chaudhary et al., 2009), and regulate the balance of soil surface runoff and infiltration (Castillo-Monroy et al., 2010; Eldridge et al., 2010; Chamizo et al., 2012). Additionally, biocrusts can profoundly affect soil microorganisms (Castillo-Monroy et al., 2015) and have a large effect on soil ecological processes (Belnap et al., 2016). Variation in biocrust distribution or development (e.g., cover, biomass, thickness) can have major impacts on ecosystems (Kidron et al., 2012), making them potentially important indicators of the status of terrestrial ecosystems across large spatial scales. Despite this, we have a relatively poor understanding of how biocrusts vary across large gradients in soils and climate (Bowker et al., 2006b).

At a regional scale, differences in climate, topography, soil, vegetation, and disturbance are thought to regulate the distribution and development of biocrusts (Read et al., 2008; Bruun et al., 2010; Bu et al., 2014; Fischer and Subbotina, 2014; Bu et al., 2015; Rodríguez-Caballero et al., 2019). Rainfall is often positively correlated with the biomass of biocrusts and affects species composition (Drahorad et al., 2013; Bowker et al., 2016). Topographical factors and elevation alter temperature, moisture and light, and influence biocrusts indirectly. High ultraviolet radiation allows cyanobacterial crusts to dominate pediments, and higher water availability on north-east facing slopes provides a more suitable habitat for lichen crusts (Chamizo et al., 2016). A range of soil

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micronutrients (e.g., K, Zn, Mg) and fine soil texture are coupled with biocrusts, promoting biomass and species abundance (Bowker et al., 2006a). The influence of soil pH depends on biocrust type, and cyanobacteria and algae have been shown to be positively correlated with soil pH while moss crusts are not (Ponzetti and McCune, 2001; Rivera-Aguilar et al., 2009; Li et al., 2010). Vegetation cover affects the distribution of biocrusts (Dougill and Thomas, 2004; Briggs and Morgan, 2008), particularly moss crusts (Pharo and Beattie, 2010). Disturbance is typically associated with reduced biocrust cover (Belnap and Eldridge, 2001; Zhang et al., 2013), resulting in reductions in biocrust biomass, with little influence on community structure (Steven et al., 2015). Due to spatial and temporal heterogeneity, the effects of environmental factors such as soil and vegetation on biocrusts (e.g., species composition and cover) change markedly (Bowker et al., 2016). Consequently, at regional scales, these complex relationships need to be examined to determine how environmental factors drive biocrust distribution and function, so that we can develop more effective biocrust protection and soil restoration practices.

The Mu Us Sandland is a crucial ecological barrier in northern China and supports extensive areas of cyanobacteria- and moss-dominated crusts (Shao, 2015), which provide critical ecological functions. Previous studies have shown that moss crusts occupy about 7000 km^2 of the Mu Us Sandland, at an average cover of about 6.4% (Feng et al., 2015), and contribute 11.85 Tg of soil organic carbon (Li, 2018). Biocrusts also interact with *Artemisia ordosica*, the dominant plant species, reduce wind erosion, and influence the soil water conditions and vegetation succession (Xiong et al., 2011; Zhang et al., 2013; Yang et al., 2014). Climate change and human activities are likely to shift the distribution and development of biocrusts in this region (Zhang et al., 2013), but our knowledge of this is poorly developed. Therefore, understanding how environmental factors are likely to affect biocrusts and their capacity to support important ecosystem services allows us to predict how ecological functions might change with changes in climate (reduced rainfall) and land-use practices (overgrazing) (Beaugendre et al., 2017; Li et al., 2017; Rodriguez-Caballero et al., 2018). This current lack of understanding restricts the capacity to manage biocrusts effectively across such large regions.

To address this knowledge need, we used boosted regression trees and correlation analysis to examine the relationship between environmental factors and biocrusts across 40,000 km^2 of a semiarid desert in Central China. We aimed to determine the main environmental drivers of the distribution of biocrust cover, and the relationships among these environmental factors and the development of biocrusts dominated by cyanobacteria and mosses. Our study provides a more comprehensive understanding of the biocrusts in the Mu Us Sandland, offering a baseline against which we can predict the degradation and recovery of biocrusts across this broader region.

2. Materials and methods

2.1. Study sites

The Mu Us Sandland is located in northwestern China (37°31′ – 39°41′ N, 107°25′ – 110°22′ E), with an area of approximately 42,612 km^2 (Fig. 1). The Mu Us Sandland includes the entirety of Uxin Qi, the eastern part of Otog Qianqi, the southwestern region of Ordos, the

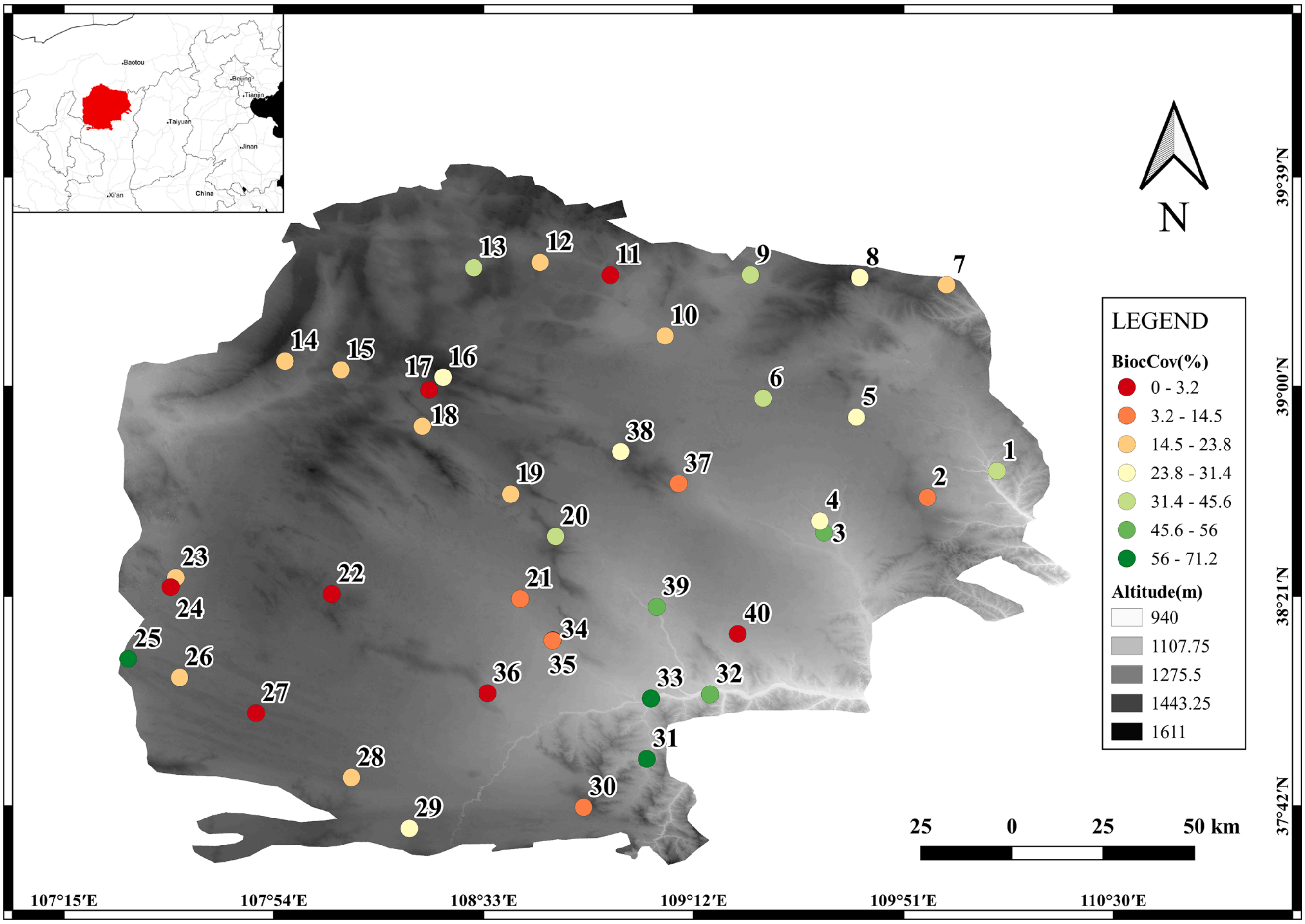

Fig. 1. The location and boundary of our study area showing the distribution of quadrats and the cover of biocrusts (BiocCov). Biocrust cover declines from the southeast to the northwest, indicating the strong negative correlation with elevation.

northern and eastern parts of Dingbian County, the northern part of Jingbian County, and the northwestern region of Yulin. It borders the Loess Plateau and Ulan Buh Desert to the southeast and northwest, respectively. With elevations from 940 to 1611 m above sea level, the terrain gently undulates from the northwest to the southeast (Karnieli et al., 2014). The climate is arid and semiarid (Li et al., 2015), and the average annual temperature ranges from 6.0 to 8.5 °C. The annual average precipitation increases from 250 to 440 mm from the northwest to the southeast and is mainly concentrated from July to September. The rainfall in August accounts for 60% – 75% of the precipitation for the whole year (Yan et al., 2013). Vegetation ranges from semi-moist forest to arid grassland and desert. The fixed and semi-fixed dunes in this area have higher vegetation coverage and plant diversity than that in other nearby deserts (Bai et al., 2006). Shrub communities dominate this area. The main species are *Salix psammophila*, *Artemisia ordosica*, *Oxytropis aciphylla*, *Salix heliophila*, and *Hippophae rhamnoides*. Biocrusts are widely distributed in this area (Fig. 2-A), and comprise mainly cyanobacterial and moss crusts (Zan, 2012). Field investigations showed that biocrusts often develop between or beneath the canopies of shrubs, such as *Artemisia ordosica* or some grasses (Fig. 2-B). Disturbance by grazing is common throughout the whole region (Fig. 2-C).

2.2. Field assessment

To clarify the relationship between biocrusts (cover distribution and development characteristics) and environmental factors (climate, soil, topography, vegetation, grazing disturbance) across such a large area, we surveyed 106 sites (June to July 2016) to assess the heterogeneity of the vegetation community and topography of the whole region (Appendix S1, Fig. S1). These surveys revealed that environments in the Mu Us Sandland have distinct zonal characteristics. We then selected 40 of the 106 sites where biocrusts were most typical and uniformly distributed, and measured the distribution and development of biocrusts, topography, vegetation, and disturbance within large (30 m by 30 m) plots (Fig. 1, Table 1).

Table 1
Environmental factors and determination methods.

No.	Factors	Apparatus and Methods
1	Latitude and longitude (°)	Garmin InReach SE + satellite GPS measured centrally in the plot.
2	Elevation (m)	Garmin InReach SE + satellite GPS measured centrally in the plot.
3	Slope and Aspect (°)	Determined by clinometer.
4	Vegetation coverage (%)	Visually assessed in nine 1 m^2 quadrats at each 30 m × 30 m site.
5	Plant richness	Total number of vascular plant species.
6	Aridity Index	Downloaded from the CGIAR CSI website (Antonio and Robert, 2019). Declining values are more arid.
7	Soil pH	Measured on soil–water volume ratio of 1 : 5 extract with pH meter (pHS-25, Shanghai Leici Instrument Factory, China) (Thomas, 1996).
8	Soil bulk density (g cm^{-3})	Oven-drying method (O'Kelly, 2004).
9	Soil organic carbon, nitrogen and phosphorus content (%)	Automatic discrete analyzer (Model Cleverchem 200, DeChem-Tech, Germany)
10	Disturb intensity (kg herbivore dung ha^{-1})	Four 30 m vertical strips were placed at 0, 10, 20, 30 m along one edge of each 30 m × 30 m site. A 1 m^2 square was set up at 10 m and 20 m of each strip, in which animal dung (mostly from sheep) was collected then dried at 105 °C and weighed indoor, to calculate the total oven-dried mass of dung per hectare as our measure of recent disturb intensity (Johnson and Jarman, 1987; Marques et al., 2001; Eldridge et al., 2017).

The sampling sites for measuring biocrust cover and development were selected based on the distribution of different biocrust types (moss and cyanobacteria). Total biocrust cover (moss plus cyanobacteria cover) was visually estimated within twelve 1 m^2 quadrats within each plot (six each for moss and cyanobacterial areas). We took intact core samples of moss (3 cm deep) and cyanobacterial (2 cm deep) crusts to assess biomass (moss crusts only), thickness, bulk density (moss crusts

Fig. 2. A typical pattern of vegetation and biocrusts (A, B). Typical distribution of moss crusts under the *Artemisia ordosica* (B). Typical grazing disturbing damage (in the red frames) on moss crusts (C). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and cyanobacterial crusts) in the laboratory. Additional soil samples were taken adjacent to moss ($n = 4$ replicates) and cyanobacterial ($n = 4$ replicates) crusts to assess soil bulk density, pH and soil total nitrogen (N), total phosphorus (P), and organic carbon (OC). We then assessed vegetation cover, plant richness, and the intensity of disturbance at the site and used available sources to determine elevation, slope, aspect, latitude and longitude, aridity index (Table 1).

2.3. Data analysis

We developed a database of 12 environmental indicators and eight indicators of biocrust cover and development for the 40 sites. First, we used boosted regression tree (BRT) models to analyse the main environmental factors driving the distribution of biocrust cover. The BRT model was fitted in R (v3.6.3, https://cran.r-project.org/, R Development Core Team, 2020) using the “dismo” library (Hijmans et al., 2017). First, we used a learning rate of 0.008 and a tree with three splits, allowing models of sufficient complexity whilst allowing for the relatively small size of the data set (Elith and Leathwick, 2017). The model was run as a Gaussian (normal) response output. The first important output from the model was a measure of the deviance explained on held-out data (using the cross-validation and showing whether the model explains important variation at new sites). Second, the relative importance of the different predictors could be assessed through their frequency of selection and their effect on the explained deviance (Elith and Leathwick, 2017). Third, the effect of each predictor on the response of biocrusts, holding other covariates at their mean effects, was visualized in partial dependence plots. The partial effects value represents the effects of a predictor on the mean of the estimation of the response variable after accounting for the average effects of the other predictors (Hastie et al., 2009). We then used Spearman’s rank correlation analysis to explore the relationships between environmental factors and the cover, thickness, and bulk density of moss and cyanobacterial crusts, and the biomass of moss crusts, and presented the data as heat maps using the “ggplot2” in the same version of R.

3. Results

3.1. Distribution and development of biocrusts

Biocrust cover ranged from 0 to 71.2% (median = 23.1%), and was greatest in the southeast and declined to the northwest, corresponding to declines in elevation (Fig. 1). Cyanobacterial crusts were thinner than moss crusts (median: 5.2 mm and 9.8 mm, respectively), but cover was greater (median: 11.5% and 5.2%, respectively). Median biomass of moss crusts was 1.87 g cm^{-3}, and the bulk density of both crust types was similar (1.5 - 1.6 g cm^{-3}; Table 2). Thirty-eight of the 40 quadrats were disturbed by grazing (median intensity: 0.47 kg ha^{-1} of dung; see Table 2).

3.2. Environmental factors and biocrust cover and development

Our final BRT model showed that all 12 variables explained 48.2% of the predicted deviance (i.e., the variation in data from quadrats withheld from model fitting) in the response of biocrust cover. Vegetation cover was the most important, followed by the aridity index and, to a lesser extent, slope, disturbance, soil pH, soil organic carbon, and elevation. Soil N and P, plant richness, aspect, and soil bulk density were relatively unimportant, with values <1% (Fig. 3).

Biocrusts tended to be greatest at plant cover levels between 43% and 55%, with sharp declines at lower plant cover levels, but more gradual declines above 55% plant cover (Fig. 4). Biocrusts were greatest on steep (>6.6°) slopes, under low herbivore disturbance intensity (<1.28 kg dung ha^{-1}), fine moisture conditions (aridity index > 0.34), and higher soil pH (>8.58). Low soil organic carbon content (<0.53%) inhibited biocrust distribution. Biocrust distribution tended to be limited above 1340 m. There were relatively no effects of soil P, N or bulk density, plant richness, or aspect on biocrust distribution (Fig. 4).

Table 2
Summary of environmental factors and biocrust coverage and development characteristics.

Variable Category	Variable names	Min.	Median	Mean	Max.
Environmental factors	Elevation (Altitude) (m)	940.00	1350.00	1310.00	1611.00
	Slope (°)	0.00	4.00	4.35	12.00
	Aspect (°)	0.00	204.00	174.60	337.00
	Plant cover (%)	0.00	55.00	51.67	90.00
	Plant richness	0	5	5	12
	Aridity Index	0.26	0.34	0.34	0.43
	Soil pH	7.47	8.66	8.59	9.25
	Soil bulk density (g cm^{-3})	1.39	1.56	1.56	1.71
	Soil N (%)	0.010	0.020	0.027	0.11
	Soil P (%)	0.0017	0.019	0.022	0.058
	Soil organic C (%)	0.10	0.46	0.56	2.13
	Disturbance index (kg dung ha^{-1})	0.00	0.47	0.86	4.23
Biocrust coverage and development characteristics	Biocrust cover (%)	0.00	23.14	25.47	71.17
	Cyanobacterial cover (%)	0.00	11.54	14.13	38.17
	Moss cover (%)	0.00	5.17	11.34	56.08
	Cyanobacterial bulk density (g cm^{-3})	0.00	1.52	1.26	1.60
	Moss bulk density (g cm^{-3})	0.00	1.50	1.11	1.60
	Cyanobacterial thickness (mm)	0.00	5.16	4.54	8.56
	Moss thickness (mm)	0.00	9.78	7.22	13.89
	Moss biomass (g cm^{-2})	0.00	1.87	2.07	7.64

The pattern of relationships among environmental factors and biocrust development was similar to the distribution of biocrusts. The strength of the relationships between environmental variables and biocrust development was generally weaker in cyanobacterial than moss crusts. Significant relationships for cyanobacteria were positive, while those for moss crusts were mixed (Fig. 5).

Moss crust cover, thickness, bulk density, and biomass increased with increasing plant cover and increasing values of the aridity index (declining dryness), but there were no significant associations for cyanobacterial crusts. Cyanobacterial crust cover positively correlated to the soil OC and P. Further, the bulk density of both moss and cyanobacterial crusts and the thickness of moss crusts increased with increasing soil OC. We also found some negative correlations, but only for moss crusts. Moss crust cover declined with increasing herbivore disturbance and at higher elevations, and biomass declined with increasing soil pH. Cyanobacterial crust thickness was positively correlated with increasing slope and aspect; the bulk density was positively related to slope. Moss crust bulk density positively correlated with aspect. Finally, moss crusts tended to have more biomass in soils with more N and OC.

4. Discussion

4.1. Environmental factors and cover distribution of biocrusts at a regional scale

Our study identified that the distribution of biocrusts in the Mu Us Sandland in northern China are driven by changes in vegetation cover, aridity index, slope, herbivore disturbance intensity, soil pH and OC,

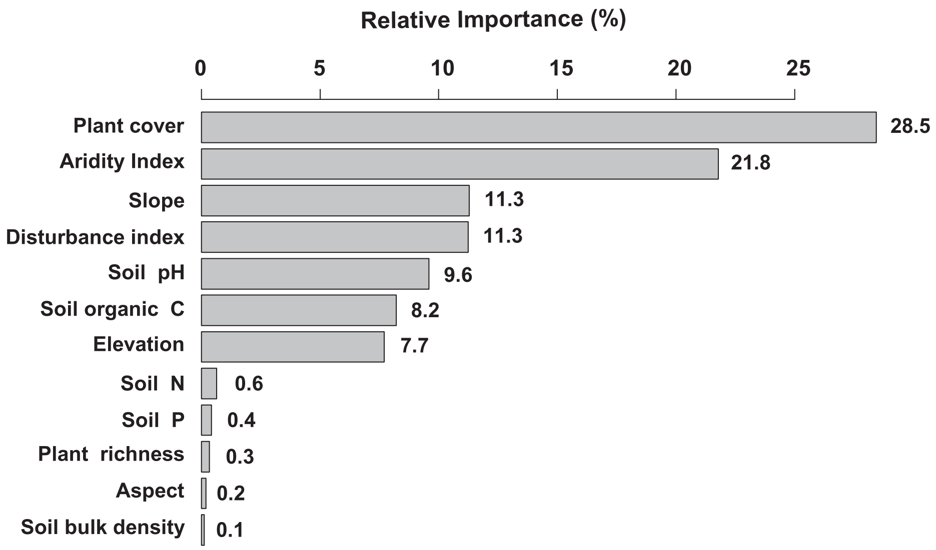

Fig. 3. The relative importance of the different predictors in the boosted regression tree model (BRT).

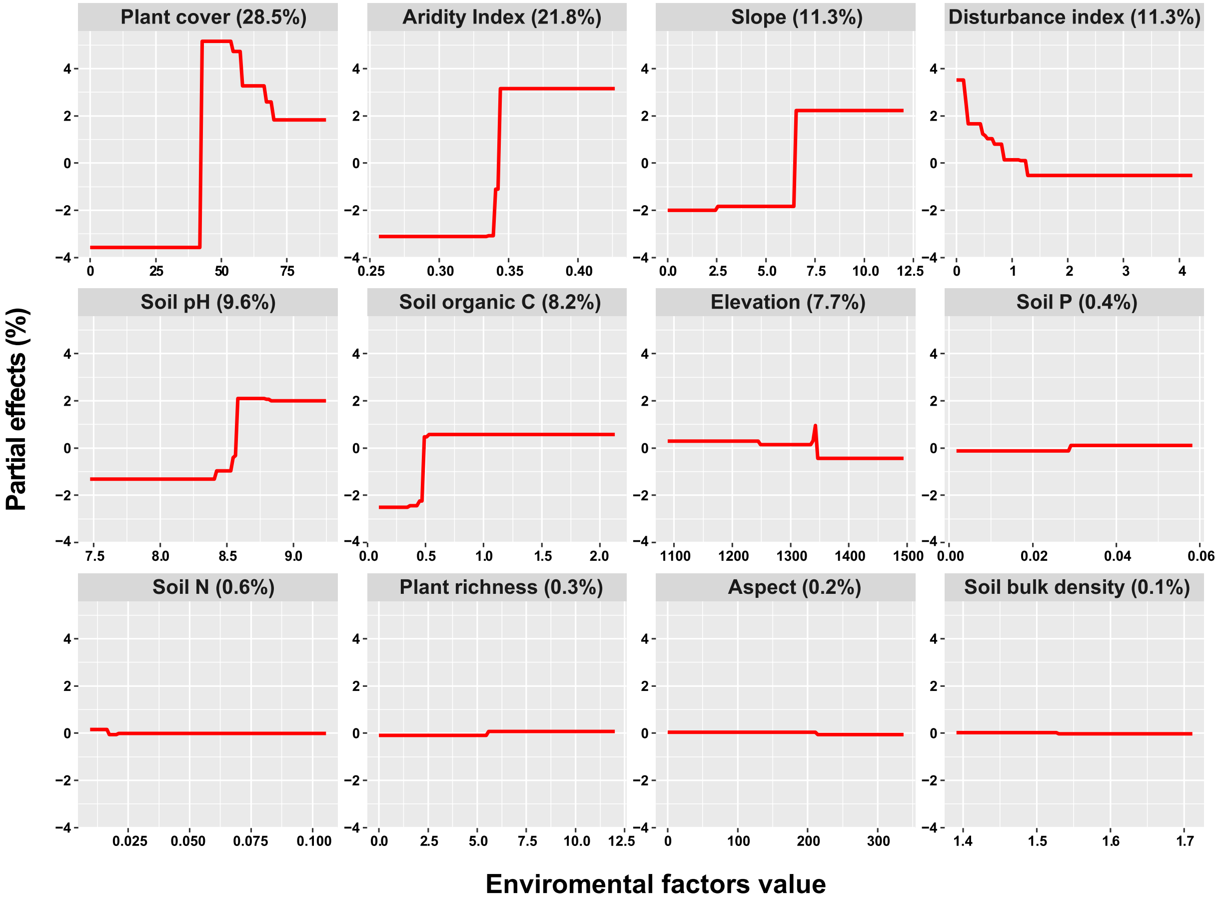

Fig. 4. Partial plots of influential variables in the boosted regression tree model (BRT) for biocrust coverage, ordered by the relative importance. The relative importance is shown as a percentage next to the variable name. The partial effects value represents the effects of a predictor on the mean of the estimation of the response variable (biocrust cover) after accounting for the average effects of the other predictors.

and elevation. High vegetation cover (>43%) likely reduces the impacts of wind erosion and increases aeolian sediment, and prolongs the retention of surface water, thereby promoting biocrust distribution (Dougill and Thomas, 2004; Briggs and Morgan, 2008). We also showed some evidence that vegetation cover above about 55% might suppress the distribution of biocrusts, potentially by intercepting rainfall (Pharo and Beattie, 2010) or shading out the crusts. While rainfall and moisture affect photosynthesis and respiration directly, vegetation is known to reduce fluctuations in soil moisture through shading, and to reduce the impacts of increasing aridity (Drahorad et al., 2013; Bowker et al., 2016). Conditions of higher moisture and temperature at lower elevations (<1334 m) would promote dense grass growth, which is known to

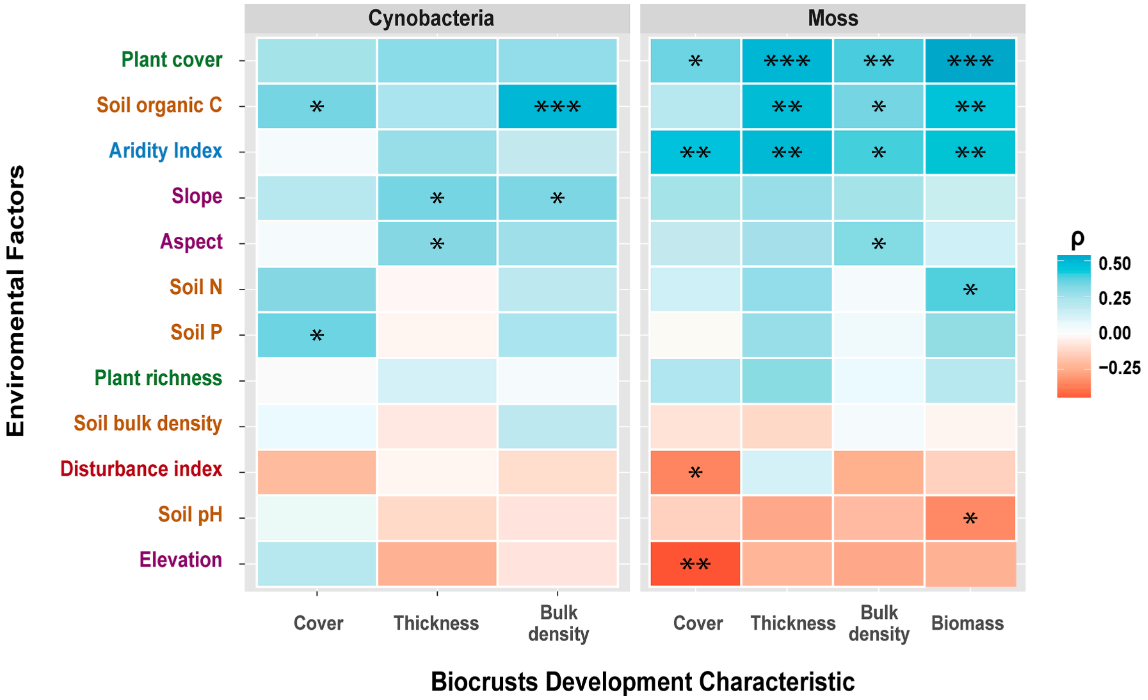

Fig. 5. Heatmaps of Spearman's rank correlation coefficients ρ between the developmental characteristics of biocrusts (cyanobacterial crusts and moss crusts) and environmental factors (climate, topography, soil, vegetation, disturbance). Only significant values ($P < 0.05$) are shown.

outcompete biocrusts (O'Bryan et al., 2009). Relatively high concentrations of OC (>0.5%) improve soil nutrients and structure promotes biocrust development (Bowker et al., 2006a; Castillo-Monroy et al., 2016). Slope likely effects biocrusts indirectly by its effect on the redistribution of water, and greater slopes (>6.7°) might be expected to reduce plants, which compete with biocrusts (Chamizo et al., 2016). Biocrusts are known to favor soils of high pH, soil pH values > 8.6 would promote their wider distribution (Rivera-Aguilar et al., 2009; Li et al., 2010).

Trampling by herbivores is the main form of disturbance in the Mu Us Sandland (Zhang et al., 2013), and damage would be restored naturally under lower (<1.15 kg dung ha^{-1}) than high intensity (>1.28 kg dung ha^{-1}) disturbances (Zhang et al., 2013). Moreover, the threshold values that we observed in our study demonstrated that the impact of environmental factors on biocrust distribution varies within a specific site. For example, the effect of increasing values of the aridity index changed little at values of <3.4 or >3.5, whereas we detected substantial changes in biocrust distribution in a narrow band of the aridity index from 0.34 to 0.35. More detailed studies would be required, in other areas, to test whether this narrow threshold is applicable to biocrust more widely.

4.2. Environmental factors and biocrust development at a regional scale

A heatmap of Spearman's rank correlation analysis revealed the relationships among environment variables and the development of cyanobacterial and moss crusts. Increasing aridity index, soil OC and N, plant cover and aspect promoted the development of moss crusts, while elevation, disturbance and soil pH showed the opposite. In general, moss crusts prefer shady and damp conditions and need to grow on a stable sand surface, particularly in the *Artemisia* communities at low elevation. *Artemisia* is the most common shrub community at the study site (Zan, 2012), and its fertile island effects creating suitable habitat for moss crusts to develop under their canopies with high thickness and biomass (Zhang et al., 2010; Zhang et al., 2013). Further, *Artemisia* is grazed by sheep and cattle, causing trampling and compacting the moss crust layer, reducing the coverage, and increasing its thickness (Zhang et al., 2013). Soil pH in our study area was relatively high (7.47 to 9.24), and was negatively correlated with moss biomass, consistent with previous studies (Ponzetti and McCune, 2001; Rivera-Aguilar et al., 2009).

As a successional pioneering species, cyanobacterial crusts were poorly related to vegetation cover, precipitation and elevation, but were positively related to topography and topsoil properties (Belnap et al., 2001; Mager and Thomas, 2011). This result may be because, early successional processes are likely driven by differences in slope and aspect, which are the main factors that reduce radiation intensity and surface temperature (Chamizo et al., 2016) and promote the development of cyanobacteria. Increasing cyanobacterial crust cover and bulk density likely result in increasing levels of organic C in the topsoil, consistent with studies by Li et al. (2017). The positive association between cyanobacterial cover and soil P may be due to the fact that cyanobacteria are pioneering species, often associated with unstable soils, and may reflect exposure of phosphorus in subsoils (Delgado-Baquerizo et al., 2013). Disturbance only slightly affected the cyanobacterial crusts, possibly because these crusts accompanied with fewer plants that are favored by herbivores. Soil pH was positively correlated with cyanobacterial crust cover, which contrasted with the negative effects of high pH on moss crusts. Topsoil modified by cyanobacteria is also suitable for moss (Li et al., 2010), which explains the boosted regression tree results, that high soil pH promotes biocrust distribution.

Our results also indicate that the distribution of biocrusts may change under future changes in climate and grazing in the Mu Us Sandland. Results from the boosted regression tree analyses indicated that if the aridity index drops below 0.34 due to high temperature and low precipitation, biocrust cover may be reduced by approximately 3%. Increased rainfall and unrestricted grazing may benefit the development of moss and cyanobacterial crusts and increase biocrust cover and biomass. In contrast, drying climatic conditions or unrestricted grazing may increase the proportion of cyanobacterial crusts and limit the proportion of moss crusts. The effects of this are largely unknown, although an increased cover of cyanobacteria would be expected to fix more nitrogen (Chen and Duan, 2014; Rodriguez-Caballero et al., 2018). A greater cover of cyanobacterial crusts at the expense of moss crusts might also reduce soil surface stability, but this will depend on the type of crust that develops. Regardless of which scenario occurs, the distribution, composition, and development of biocrusts will change, potentially resulting in substantial effects on ecological functions (Belnap et al., 2016; Rodriguez-Caballero et al., 2018).

At a regional scale, our analyses demonstrated that the distribution and development of biocrusts are governed by the combined effects of climate, topography, soil, vegetation, and disturbance. However, we have not explicitly considered lichen-dominated biocrusts in our analyses, as our placement of plots and quadrats was based on moss and cyanobacterial crusts. Therefore, our study has potential limitations if we are to predict future effects of the changes in climate and land-use on all biocrusts and therefore their impacts on regional scale ecological function. These limitations could be rectified by implementing a framework to measure the impact of environmental changes (e.g., climate change and grazing) on the distribution and development of different biocrust types. Under constant precipitation levels, and maintaining disturbance intensity below 1.15 kg dung ha^{-1}, the distribution of biocrusts would remain stable or increase (Zhang et al., 2013), moss crusts would expand in shrub communities at low elevation, and cyanobacterial crusts would likely migrate to bare soils with adequate moisture and stability at high elevation. More research is needed to clarify the comprehensive impacts of disturbance and climate change, and to map the ecological sensitivity of biocrusts to environmental changes. This would improve our capacity to quantify the ecological impacts of changes in biocrust distribution and development as we move towards an environment where climates are hotter and drier.

5. Conclusions

Our study identifies those environmental factors that drive biocrust distribution and development in the Mu Us Sandland at a regional scale. Vegetation cover, aridity index, slope, disturbance intensity, soil pH, soil organic carbon, and elevation were the main factors affecting biocrust distribution. Mapping the distribution of biocrust communities is the first step towards protecting and managing biocrusts in an area that is sensitive to changes in environmental conditions. More research is needed to clarify the comprehensive impacts of disturbance and climate change, and to provide more comprehensive mapping of the ecological sensitivity of biocrusts to environmental changes. This would improve our capacity to quantify the ecological impacts of changes in biocrust distribution and development as we move towards an environment where climates are hotter and drier.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.catena.2020.105137.

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