Journal of Arid Environments 124 (2016) 31–38

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Biocrust structure responds to soil variables along a tropical scrubland elevation gradient

Andrea P. Castillo-Monroy [a, *], Ángel Benítez [b], Fabián Reyes-Bueno [a], David A. Donoso [b], Augusta Cueva [a]

[a] Departamento de Ciencias Naturales, Universidad Técnica Particular de Loja, San Cayetano Alto, Loja, Ecuador
[b] Museo de Colecciones Biológicas MUTPL, Departamento de Ciencias Naturales, Universidad Técnica Particular de Loja, Loja, Ecuador

A R T I C L E I N F O

Article history:
Received 13 February 2015
Received in revised form
20 June 2015
Accepted 29 June 2015
Available online xxx

Keywords:
Lichens
Mosses
Cyanobacteria
Species richness
Abundance
Elevation gradient

A B S T R A C T

Biocrusts are composed of diverse organisms including bryophytes, lichens, archaea, bacteria, cyanobacteria, microfungi, and green algae. While biocrusts are distributed worldwide, most of our knowledge comes from temperate regions, and scarce information is available from tropical regions. We aimed to: i) generate the first map of potential areas of occurrence of biocrust in Ecuador, ii) describe the structure of biocrust components along an elevation gradient predicted by our map analysis to support biocrusts. Our maps identified 9145 km^2 as potential area for the occurrence of biocrusts, which represents 18% of Ecuadorian drylands. Our study site was located in mountain shrubland in southeastern Ecuador. Species richness increased with elevation and species composition was significantly different among elevation levels. The abundance of species forming biocrusts was related to several soil variables, including pH and fine texture. Our results provide insights into the importance of soil variables as drivers of biocrust composition and abundance in the tropics. Moreover, the information generated in this study could be useful in assigning conservation priorities to Ecuadorian drylands. Thus, our results help fill current gaps in our knowledge of biocrusts and add to the scant literature dealing with these organisms in tropical drylands.

1. Introduction

Biological soil crusts, or biocrusts, are important components of soil ecosystems. They are composed of phylogenetically and functionally diverse organisms including macroscopic bryophytes (e.g., mosses and liverworts) and lichens, and microscopic archaea, bacteria, cyanobacteria, microfungi, and green algae (Belnap and Lange, 2003). These organisms form intimate associations with surface soil and are a major component of arid ecosystem biodiversity. Biocrusts also play a prominent role in ecosystem functions, including biological nutrient cycling (e.g., carbon and nitrogen fixation Belnap (2002)). Biocrusts confer resistance to erosion (Chaudhary et al., 2009) and modulate soil nutrient mineralization, total carbon released by soil respiration, and water runoff-infiltration balance (Castillo-Monroy et al., 2010, 2011a; Eldridge et al., 2010). They influence the distribution and abundance of plants and animals (Shepherd et al., 2002; Belnap and Lange, 2003). In addition, biocrusts exert both positive and negative influence on communities of microfauna (Neher et al., 2009), and soil microorganisms (Castillo-Monroy et al., 2015) such as fungi (Bates et al., 2010) and bacteria (Castillo-Monroy et al., 2011b).

Biocrusts are distributed worldwide, and have been studied in many countries and dryland soil ecosystems (e.g. United States, Australia, Spain, China, Israel, Mexico; Castillo-Monroy and Maestre (2011)). While the dynamics and ecology of biocrust in arid and semi-arid land of subtropical regions have been well documented over the last decade (Belnap and Lange, 2003; Maestre et al., 2011), fewer investigations have been undertaken in temperate regions, and these have been focused mainly on floristic and phytosociology rather than function (Belnap and Lange, 2003). Furthermore, very little information is available from the tropical world (but see Rivera-Aguilar et al. (2006), Büdel et al. (2009)) despite the fact that climatic and edaphic conditions of large areas seem to be well suited for the development of rich terrestrial cryptogrammic vegetation in South America (Belnap and Lange, 2003; Castillo-Monroy and Maestre, 2011). Owing to human-related activities,

* Corresponding author.
E-mail address: apcastillo4@utpl.edu.ec (A.P. Castillo-Monroy).

http://dx.doi.org/10.1016/j.jaridenv.2015.06.015
0140-1963/© 2015 Elsevier Ltd. All rights reserved.

tropical drylands are ranked among the most threatened ecosystems worldwide and are considered a priority conservation concern (Wale and Dejenie, 2013). Nevertheless, little is known of the patterns of distribution and abundance of biocrust-forming lichens, cyanobacteria and mosses at large spatial scales in the tropical regions(but see San José and Bravo, 1991; Castillo-Monroy and Benítez, 2015).

Changes in species richness along elevation gradients are among the most commonly considered aspects of biotic community structure (Lomolino, 2001). However, it is not yet known whether a general relationship exists between species richness and elevation or even whether a universal explanation or model can be formulated. Several altitudinal patterns of species richness and distribution have been reported, including positive and negative associations between richness and elevation or a hump-shaped distribution with no obvious trend at all. Some biocrust components, such as mosses, lichens and cyanobacteria, have been well studied with respect to with elevation gradients. Sun et al. (2013) described the distribution pattern of terrestrial bryophytes along an altitudinal gradient from subtropical to alpine cold areas in southwestern China, and found no clear elevation trend. Baniya et al. (2010) compared distribution patterns of different life forms along the Nepalese Himalaya elevation gradient between 200 and 7400 m, and found that the total number of terricolous lichens showed a slightly bimodal distribution. Choudhary and Singh (2013) evaluated cyanobacterial diversity using soil samples from different altitudes in the Eastern Himalayan region of India and found that species diversity was negatively correlated with altitude. These biocrust components, however, have not yet been studied as a community. To our knowledge, no previous studies have investigated small-scale patterns of abundance of lichens, cyanobateria and mosses forming biocrusts in a South American tropical ecosystems, nor have they evaluated how these vary with changes in altitude. We aimed to test this in a dry mountain shrubland from Ecuador. Our objectives were to: i) generate a map of potential areas of biocrust occurrence in Ecuador, and, ii) describe the structure of macroscopic biocrust components — bryophytes, lichens and cyanobacteria — along an elevation gradient in a mountain shrubland in south Ecuador. We previously identified and described macroscopic biocrust components along this gradient and showed that species richness increased with elevation (Castillo-Monroy and Benítez, 2015). Here we present a community-based approach with new analyses to reveal the degree of similarity of species cover at different elevation levels. We further examine the multivariate relationships between species cover and the measured soil variables using non-metric MDS ordination and a stepwise distance-based linear model permutation test, respectively. While diversity theory based on vascular plant studies predicts that species numbers should be highest at intermediate levels of environmental stress (Grime, 1973), we hypothesized that elevation could exert a significant and positive influence on biocrust component richness because more water availability and lower temperatures are found at higher than at lower altitudes in our study site (Espinosa et al., 2013). Our results will establish a baseline of macroscopic biocrust biodiversity in this region and enrich our understanding of the ecology of biocrusts in tropical ecosystems.

2. Materials and methods

2.1. Potential areas of occurrence of biocrust in Ecuador

As soil-biocrust (non-vascular) organisms have a limited ability to grow upwards from the soil surface, they are generally unable to compete with vascular plants for light. Consequently, biocrust development is reduced where conditions permit development of a closed vascular plant canopy or thick litter layer (Belnap and Lange, 2003). Their requirements are mainly low moisture and high tolerance to extreme temperatures and light (Funk et al., 2014). We use these characteristics in a map of temperature and precipitation because those factors mainly influence the distribution and composition of biocrusts (Belnap and Lange, 2003). To provide information on the range of temperatures and precipitation where the biocrust could occur, we evaluated patterns of abundance and distribution of biocrust using data from all of the Americas. Searches were conducted using the ISI Web of Knowledge (http://apps.isiknowledge.com) on December 5th, 2014, with no restriction on publication year. The search yielded 33 references. We identified >18 °C and <900 mm (temperature and precipitation, respectively) as the most general climatic conditions of biocrusts. Although this may be true at temperate and tropical temperatures, biocrusts have also been documented in the polar desert and semi desert of the high Arctic and Antarctic cold desert (Belnap and Lange, 2003).

To generate the map, we used bioclimatic information from standard maps of Ecuador (Melo et al., 2011) and the land cover classification from 2008 (Sociobosque, 2012). First, we generated a new layer with the spatial intersection of specific bioclimatic classes of drylands (arid, semi-arid, dry, and sub-humid). We then clipped from this first layer the land cover classes of interest (wastelands, scrublands and grasslands). The resulting map summarized potential areas of the occurrence of biocrust in Ecuador. Finally the proportion of these areas under some protection status was assessed. Spatial analyses were carried out using standard GIS shape files with ArcGIS software.

2.2. Site description

We used a preliminary occurrence map to further select a study site predicted to sustain biocrust. Due to logistical constrains, the chosen study site lies within the Catamayo Experimental Field Site (Finca Alamala), in a dry mountain shrubland in southeastern Ecuador (Fig. 1). The climate is tropical dry, with an average rainfall, evapotranspiration and temperature of 382 mm, 1112 mm, and 27.5 °C respectively, and a pronounced drought lasting from May to December (Espinosa et al., 2013). Perennial plant coverage is below 55% and is dominated by an evergreen shrub group (*Croton* aff. *thurifer* Kunth and *Croton* aff *ferrugineus* Kunth complex), which grows up to 2-m high, comprises 40% of total cover, and forms

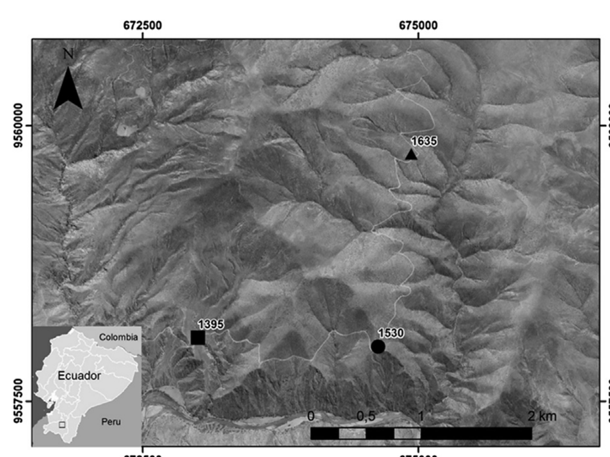

Fig. 1. Map of the three plots located in the Catamayo experimental field site (Finca Alamala), in a dry mountain shrubland in southeastern Ecuador.