Global Ecology and Conservation 14 (2018) e00404

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Original Research Article

Soil indicators of plant diversity for global ecoregions: Implications for management practices

Ji-Zhong Wan [a, b], Qiang-Feng Li [b], Ning Li [b], Jian-Hua Si [b], Zhi-Xiang Zhang [c], Chun-Jing Wang [a, b, *], Xi-Lai Li [b], Zong-Ren Li [b]

[a] State Key Laboratory of Plateau Ecology and Agriculture, Qinghai University, Xining, 810016, China
[b] College of Agriculture and Animal Husbandry, Qinghai University, Xining, 810016, China
[c] School of Nature Conservation, Beijing Forestry University, Beijing, 100083, China

ARTICLE INFO

Article history:
Received 9 April 2018
Received in revised form 9 June 2018
Accepted 9 June 2018

Keywords:
Conservation management
Ecoregional plant richness
Soil variable
Vulnerability assessment
Worldwide

ABSTRACT

Environmental indicators have been developed widely to promote biodiversity conservation, ecological restoration, and nature resource management from local to global scales. Ecoregions are effective tools for global conservation of plant diversity, and soil conditions can affect the plant diversity within ecoregions. Hence, soil indicators of plant diversity have substantial potential as tools for effectively understanding global ecoregions. Here, we used plant diversity data from 361 ecoregions and seven soil variables in a regression analysis to explore the relationships between soil and ecoregional plant diversity (EPD). We found that soil means and heterogeneity were significantly related to EPD. EPD decreased curvilinearly as both mean cation exchange capacity and mean soil pH increased, while mean soil organic carbon stock was negatively related to EPD ($P < 0.05$). EPD increased curvilinearly with mean soil texture clay fraction and mean soil texture silt fraction ($P < 0.05$). Heterogeneity of bulk density, cation exchange capacity, and soil pH had positive relationships with EPD ($P < 0.05$). EPD had a negative, unimodal response to soil organic carbon stock heterogeneity, with an opposite trend in heterogeneity of soil texture clay fraction ($P < 0.05$). Furthermore, such relationships may depend on the vulnerability of ecoregions of interest. Specially, means of soil texture clay fraction and heterogeneity of bulk density were useful indicators of EPD for relatively stable or intact and vulnerable ecoregions ($P < 0.05$), and mean cation exchange capacity and heterogeneity of soil organic carbon stock were useful indicators of EPD in critical or endangered ecoregions ($P < 0.05$). Hence, monitoring soil conditions should be conducted for plant diversity at broad scales, and conservation efforts should focus on soil diversity, with a particular emphasis on relatively stable or intact ecoregions worldwide.

1. Introduction

Ecological processes are thought to depend on plant diversity globally (Hooper and Vitousek, 1997; Tilman et al., 1997; Díaz et al., 2007; Quijas et al., 2010). Plant diversity plays an important role in community stability, ecosystem productivity, and ecological services, each of which are highly beneficial to human beings and economic development (Jain, 2000; Díaz

* Corresponding author. College of Agriculture and Animal Husbandry, Qinghai University, Xining, 810016, China.
E-mail address: wangchunjing00@163.com (C.-J. Wang).

https://doi.org/10.1016/j.gecco.2018.e00404

et al., 2007; Letourneau et al., 2011; Ruiz-Benito et al., 2014; Hanley et al., 2015). However, rapid global changes (e.g., intensive human activities, climatic change, and biological invasion) pose substantial threats to plant diversity (Tilman and Lehman, 2001; Levine et al., 2003; Thuiller et al., 2005; Liao et al., 2015). Hence, the conservation of plant diversity at global scales is urgent. Olson et al. (2001) delineated ecoregions as relatively large units of land containing a distinct assemblage of natural communities and species. The boundaries of the land units approximately reflect the original extent of natural communities prior to major land-use changes (Olson et al., 2001). Furthermore, ecoregions are widely used for conservation actions (Olson et al., 2001; Beaumont et al., 2011; Watson et al., 2013). Previous studies have shown that climate change is an effective indicator of plant diversity at the ecoregional scale, and these studies have assessed the vulnerability of plant diversity to future climate change (Watson et al., 2013; Eigenbrod et al., 2015; Young et al., 2017; Wan et al., 2017, 2018). However, climate is not the only driver of plant diversity (Van Der Heijden et al., 2008; Bernhardt-Römermann et al., 2015; Hautier et al., 2015). To improve the effectiveness of plant diversity conservation, it is important to develop other indicators of plant diversity to better monitor the dynamics of ecoregional plant diversity (EPD; Kier et al., 2005; Watson et al., 2013).

The drivers of plant diversity at broad spatial scales are actively debated within conservation ecology (Kreft and Jetz, 2007; Van Der Heijden et al., 2008; Bobbink et al., 2010). Plant diversity is often shaped by abiotic factors through environmental filtering (Laliberté et al., 2014; Stein et al., 2014). The mechanisms through which environmental means and environmental heterogeneity vary at broad spatial scales may provide a key to understand the strength of environmental filtering (Tilman and Lehman, 2001; Kreft and Jetz, 2007; Lundholm, 2009; Laliberté et al., 2014; Stark et al., 2017). Within a given geographic area, plant diversity can be driven by environmental means or by environmental heterogeneity (Tamme et al., 2010; Stein et al., 2014). The environmental mean hypothesis states that the mean environmental conditions over a given area filter plant diversity, and environmental heterogeneity can affect the ability of different plant species to adapt to certain areas (Baraloto and Couteron, 2010; Scherrer and Körner, 2011; Stark et al., 2017).

Previous studies have shown that climate means and heterogeneity can both drive patterns and processes of plant diversity at the ecoregion sale (Midgley et al., 2002; Kier et al., 2005; Watson et al., 2013; Rundel et al., 2016). However, the roles of soil means and heterogeneity in the dynamics of plant diversity should be considered at the scale of ecoregions. Soil means and heterogeneity can independently explain different proportions of the variance in plant diversity across different spatial scales, although climate may be correlated with soil means and heterogeneity (Stohlgren et al., 1999; Van Der Heijden et al., 2008). Heterogeneity in nutrients, acidity, and diversity of soil types contribute to plant diversity (Ricklefs, 1977; Bedford et al., 1999; Roem and Berendse, 2000; Lundholm, 2009). Hence, to understand the environmental indicators of plant diversity, researchers should determine whether soil means and heterogeneity can be indicators of plant diversity at ecoregional scales (Stein et al., 2014). Thus, effective indicators for conservation of EPD based on soil means and heterogeneity can be developed.

The considerable threat to suitable environmental conditions posed by intensive anthropogenic disturbances may affect the relationships between environmental conditions and plant diversity at broad spatial scales (Jain, 2000; Tilman and Lehman, 2001). Hence, the consideration of ecoregional vulnerability can help clarifying the relationships of soil means and heterogeneity with plant diversity. Accordingly, we need to integrate ecoregional vulnerability into the development of indicators to promote more effective management practices (Kier et al., 2005; Watson et al., 2013).

To develop the indicators of EPD based on soil means and heterogeneity, we assess the following subjects: (1) the relationships of soil means and heterogeneity with EPD and (2) the important indicators of ecoregional vulnerability relevant for management practices. Here, we examine plant diversity, based on diversity data from Kier et al. (2005), as well as quantified soil means and soil heterogeneity using soil maps, based on a global compilation of soil profile data and publicly available remote sensing data (Hengl et al., 2017). Then, regression models (both linear and quadratic models) were used to explore and identify these relationships between plant diversity and both soil means and soil heterogeneity (Wu et al., 2017). Finally, we developed monitoring indicators of plant diversity based on both soil means and soil heterogeneity as well as vulnerability in order to inform future management practices across global ecoregions.

2. Materials and methods

2.1. Ecoregional plant diversity data

The vector map of global ecoregions was obtained from the study conducted by Olson et al. (2001), which delineated 867 ecoregions. Kier et al. (2005) presented a global map of vascular plant species richness organized by ecoregion based on results from the published literature. We used high-quality plant diversity data for ecoregions to examine the relationship between plant diversity and both soil means and soil heterogeneity (Kier et al., 2005). Finally, we used robust, high-quality diversity data for 361 ecoregions for further analysis (Kier et al., 2005). The degrees of vulnerability of 361 ecoregions used in the present study included (1) critical or endangered, (2) vulnerable, and (3) relatively stable or intact statuses (Olson et al., 2001). The map of above-mentioned 361 ecoregions was downloaded from https://www.worldwildlife.org/.

2.2. Soil data

The soil predictors were downloaded from the SoilGrids1km database (Hengl et al., 2017; https://soilgrids.org/). These soil predictors include bulk density (kg), cation exchange capacity (cmolc/kg), soil texture clay fraction (%), volumetric coarse-