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Using legumes as indicators in the seasonally dry vegetation types in South America

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ABSTRACT

The South American corridor of seasonally dry vegetation (SACSV) includes different types of physiognomies forming a continuous corridor with high biodiversity and endemism; however, little attention has been paid to the conservation of the SACSV. As this is an area with great diversity, cataloguing all the species is challenging. Thus, we suggest the use of Leguminosae species (trees and shrubs) as bioindicators of the different types of vegetation present in the area and to identify priority areas for conservation of the SACSV, since the family is highly represented in this vegetation. The study area was divided into 358 grid cells with recorded specimens. For each grid cell, species richness, taxonomic diversity, number of species restricted to one type of vegetation, and threatened and indicator species of phytogeographic domain were calculated. To determine the phytogeographic domains and indicator species, analysis of similarity, cluster and indicator species (ISA) were performed. The results show that 43% of the grid cells (154) have high biological importance for conservation (high taxonomic diversity, species richness and number of restricted species), all of which lie outside of protected areas. We identified 72 indicator species for seven floristic units, which, in general, include areas of the same phytogeographic domain, supporting the existing classification systems. We suggest that for effective conservation of biodiversity present in the SACSV, it is necessary to establish protected areas throughout the SACSV.

1. Introduction

The seasonally dry vegetation of South America (Fig. 1) includes different types of vegetation (Chaco xeric woodlands, savannas, seasonally dry forests and thorny woodlands) occurring over a wide geographical and altitudinal range as well as a wide variety of environmental conditions (Pennington et al., 2006). Despite this, these areas have in common a seasonal rainfall and a long dry season with species adapted to stressful climatic conditions, such as spiny, deciduous plants with small leaves and other xerophytic traits (Furley and Metcalfe, 2007). The largest areas of seasonally dry vegetation on the planet are found in South America (Miles et al., 2006). These vegetation types have formed a continuous corridor of seasonal dry vegetation in this region (Prado and Gibbs, 1993; Mogni et al., 2015) with high biodiversity and endemism of species (fauna and flora). We call this area the *South American corridor of seasonally dry vegetation* (SACSV).

The distinct types of vegetation of the SACSV have been altered by human activities (high rates of deforestation and habitat fragmentation), and little attention has been paid to their conservation when compared with tropical rainforests (Overbeck et al., 2015; Gentry, 1995; Murphy and Lugo, 1995). According to Werneck (2011), the percentage of strictly protected areas of SACSV ranges from only 1% to 2.2% of its extension. This is alarming because this vegetation is poorly known and deeply threatened by anthropogenic disturbances (Mooney et al., 1995) and the documentation of the few remaining areas are of great importance for conservation planning (Lima et al., 2015). The flora of the SACSV is highly diverse with Leguminosae being among the most representative families (Gentry, 1982, 1988, 1995; Wojciechowski et al., 2004). A strategy that can be used to study large areas with high species richness is to select indicator groups consisting of species belonging to taxa with high richness to be used as models to prioritize areas for conservation (Loyola et al., 2007).

Leguminosae is composed of roughly 751 genera with approximately 19,500 species ranging from tall trees to small herbs (LPWG,

Abbreviations: SACSV, South American corridor of seasonal vegetation; HBI, high biological importance; VHBI, very high biological importance; EBI, extreme biological importance.

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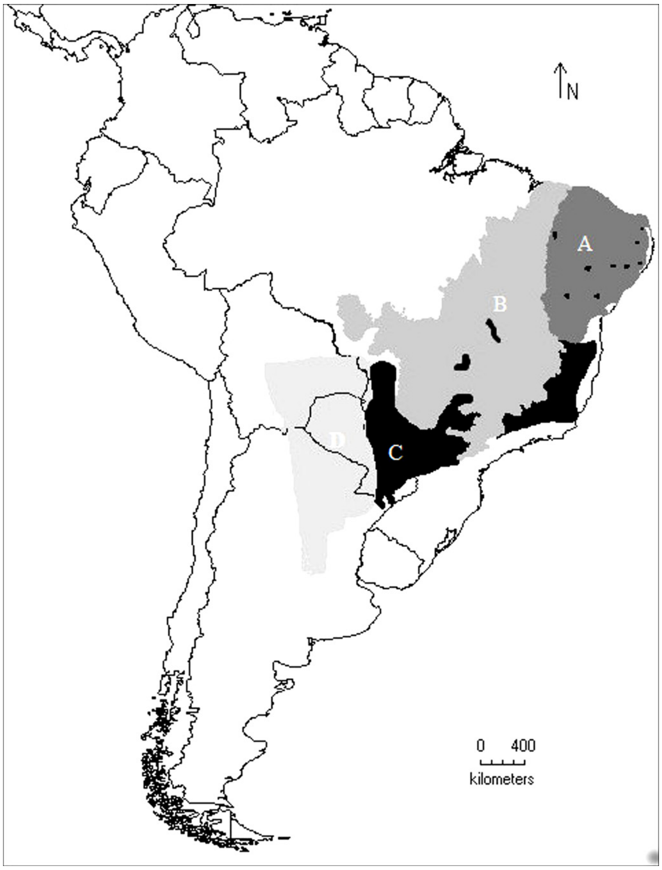

Fig. 1. Map of the South American corridor of seasonally vegetation highlighting the largest areas of seasonally dry vegetation. Thorny woodlands (A), Brazilian savannas (B), seasonal forests (C or black) and Chaco (D).

2013). It is the third largest flowering plant family in the world (Lewis et al., 2005). The family has a cosmopolitan distribution and is among the richest families in number of species in neotropical forests (Gentry, 1982, 1988, 1995) with a higher diversity in seasonally dry forests and shrubby temperate vegetation with xeric climate (Wojciechowski et al., 2004). This family has an evolutionary history strongly associated with its occurrence in seasonally dry vegetation (Lavin et al., 2005; Schrire et al., 2005). It also has a wide geographical distribution along the SACSV (see Lima et al., 2015; Schrire et al., 2005) and, thus, is an ideal model to use to search for indicator species of the different types of vegetation present there and to identify priority areas for conservation of the SACSV.

In this study we used this family as a proxy to determine areas of high biological importance along the SACSV. Considering the biological model and region analyzed (Leguminosae in SACSV), the framework involved the following steps: (1) to evaluate species richness, taxonomic diversity of areas, species restricted to one type of vegetation and threatened trees and shrubs species of Leguminosae, (2) to examine the floristic affinities between different areas of SACSV and the indicator species and (3) to indicate priority areas for conservation.

2. Materials and methods

2.1. Study area

South America occupies about 12% of the Earth's land surface and is among the most diverse continents on Earth. The vegetation ranges from rainforest (Amazon and Atlantic forest) to seasonally dry vegetation (Brazilian savanna, Chaco xeric woodlands, seasonally dry forest and thorny woodland), thus housing a high biodiversity. Seasonally dry vegetation types studied here, located in the central portion of the continent, represent the largest remainder of this type of vegetation (Miles et al., 2006) and form the SACSV (Prado and Gibbs, 1993; Mogni et al., 2015). The Brazilian savanna (known locally as *Cerrado*) covers an area of about two million km^2 along the Paraguay and Parana Rivers in the states of Goiás, Mato Grosso and Mato Grosso do Sul, Brazil (Ratter et al., 1988). It occurs in areas with a seasonal climate with wet summers and dry winters and nutrient-poor, acidic soils with high levels of aluminum saturation (Gottsberger and Silberbauer-Gottsberger, 2006). The Chaco occurs in the south-central region of South America and covers an area of approximately one million km^2 occupying areas of Argentina, Paraguay, Bolivia and the extreme western part of the state of Mato Grosso do Sul, Brazil (Prado and Gibbs, 1993). The climate is seasonal, however with more severe summers and winter frosts (Werneck, 2011). The seasonally dry forest covers an area of about 700,000 km^2 in the Neotropics (Miles et al., 2006), located in areas with a strong seasonal climate (Holdridge, 1967; Murphy and Lugo, 1995) with rainfall ranging from 700 to 1600 mm/year with a period of at least five to six months with rainfall below 100 mm (Gentry, 1995). The thorny woodland (known locally as *Caatinga*) is found in the semiarid region of northeastern Brazil and covers an area of about 800,000 km^2 (Sampaio, 1995; Miles et al., 2006). The average annual rainfall ranges from 240 to 1500 mm, and the rainy season is concentrated in a period of 3–5 months, followed by a dry period of 7–9 months (Sampaio, 1995).

2.2. Database of Leguminosae species (trees and shrubs) in SACSV

The list of Leguminosae species (trees and shrubs), abbreviated hereafter as *Lts*, found in the SACSV was obtained from information present in 281 floristic lists and information from herbaria (EAC, HUEFS, INTA, IPA, K, MO, NY, RB, and SI) (for more details see Lima et al., 2015). We only used data of trees and shrubs because they are collected more frequently in floristic and phytosociological studies and, in general, are more easily identified. The names of the species were corrected for synonymy according to http://www.theplantlist.org and the site work by seed plants diversity of Brazil (BFG, 2015). All our databased specimens are georeferenced.

2.3. Species richness, taxonomic diversity, and restricted and threatened species of Lts of the SACSV

The total number of species (richness), the taxonomic distinctness index (Δ^+ – Clarke and Warwick, 1998) and species of *Lts* restricted to one type of vegetation were estimated using $1^\circ \times 1^\circ$ grid cells (358 grid cells with record specimens). The species occurrence points were imported into GIS software (Geographic Information System) and converted to shapefile format. This layer was overlaid with a layer of numbered grid cells generated based on a shapefile related to the limits of the South American continent. Analyses were performed using ArcGIS version 10.1.

We calculated the Δ^+ using PAST software (Hammer et al., 2001) according to the following formula: $\Delta^+ = [\sum\sum_{i<j} \omega ij]/[s(s-1)/2]$, where s is the number of species and ωij is the phylogenetic/taxonomic path length between species i and j). The main premise of Δ^+ is that the diversity is greater in a community in which the species are taxonomically more distinct, i.e., belonging to a greater number of higher-level taxa (e.g., genera, families).

In the present study, restricted species were defined as those occurring in just one type of vegetation, according to the species list of Lima et al. (2015). Based on these data, we constructed richness, Δ^+ and restricted species maps from the grid cells across the SACSV.

To determine areas with high biological importance for conservation, we constructed a map of protected areas of South America

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