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Fragmentation as a key driver of tree community dynamics in mixed subtropical evergreen forests in Southern Brazil

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ABSTRACT

The study of tree community dynamics may help improve our understanding of forest ecosystem function. Here, we aimed to investigate the influences of climate, soils, landscape, forest structure, and chronic anthropogenic disturbances on tree community demography in the fragments of Araucaria Forest in Southern Brazil. Nine forest fragments were inventoried between 2008 and 2012, and were inventoried again from three to six years later. For the tree community in each forest remnant, we calculated mortality, recruitment, basal area loss- and gain, net changes, and turnover rates. For each study area, we also measured altitude, climate, soil type, fragment patch metrics, cattle presence, and tree component structure. We used Principal Component Analyses (PCA) to order the multivariate data (Tree community dynamics: demographic rates; Climate: altitude + climate; Patch metric: area + core + shape + Cai). The relationships between the patterns of the dynamics and the explanatory variables were subjected to regression tree analyses and t tests. We found that the Araucaria Forest dynamics mainly varied in terms of tree mortality and basal area loss rates. In general, mortality and basal area loss rates were smaller within larger fragments, which had a greater proportion of interior areas. Therefore, we concluded that anthropogenic fragmentation is a key driver of tree community dynamics in the Araucaria Forest of Southern Brazil. Based on our results, we would recommend (i) the protection of small and large tracts of forest fragments; and (ii) incentives to promote the silviculture of the most relevant timber species, the light demanding *Araucaria angustifolia*, in the deforested lands of the region.

1. Introduction

At present, human activity is a major force driving planetary change. For this reason, it has been proposed that the present era be named the Anthropocene (Smith and Zeder, 2013; Malhi et al., 2014). Human activity has resulted in the extensive loss of natural areas and the fragmentation of forest ecosystems. Forests are of global importance in that they maintain the climate, biogeochemical cycles, and biodiversity, among other environmental factors. Therefore, studies focusing on how human activities interact with environmental factors and their effects on forest function and dynamics are considered highly relevant (Wright, 2005; Malhi et al., 2015; Uriarte et al., 2016).

Permanent-plot monitoring is regarded as one of the best approaches to investigate spatiotemporal changes in the tree components of forest ecosystems. In tropical forests, studies of this nature have been conducted in areas exposed to different levels of disturbance. Such areas range from ancient sites (Phillips et al., 2004; Malhi et al., 2015) to sites at different stages of post-disturbance recovery (Chazdon et al., 2005; Aryal et al., 2014; Laurance et al., 2014). Research on the functional ecology of various tree species (Condit et al., 1996; Pessoa and Araujo, 2014; Visser et al., 2016) has indicated that, over time and space, floristic and structural changes of the tree components occur in response to relative differences in the performance of species within a given environment. Tree performance may be expressed in terms of demography (mortality, recruitment, growth, and other criteria).

Studies in tropical regions have shown that tree component dynamics and primary productivity are influenced by the interactions of climate, soil, disturbance, and landscape (Chazdon et al., 2005; Malhi

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et al., 2015; Uriarte et al., 2016; Wagner et al., 2016). Uriarte et al. (2016) reported that anthropogenic disturbances and fragmentation increase the vulnerability of forests to extreme climatic effects and delay succession by favoring pioneer species, which tend to have relatively high mortality rates (Van Breugel et al., 2007). Drought negatively influences tree species recruitment, survival, growth (Uriarte et al., 2016), and primary forest productivity (Malhi et al., 2015, Wagner et al., 2016). Drought also increases tree component mortality (Chazdon et al., 2005; Rolim et al., 2005). Thus, in non-stationary and heterogeneous environments, demographic variations in the tree component occur because of complex interactions among the regional species pool, the disturbance regime, the landscape, and climatic conditions (Uriarte et al., 2016).

There is extensive evidence for the impact of climate, soil, landscape, and anthropogenic disturbances on tropical areas. Nevertheless, little is known about the impact of these factors in subtropical regions (Zhou et al., 2013). Therefore, in the present study, we focused on the Brazilian Mixed Subtropical Evergreen Forest, also known as Araucaria Forest, which forms part of the southern portion of the Brazilian Atlantic Forest. This region is considered to be a global biodiversity conservation hotspot.

The canopy of Araucaria Forest is populated by *Araucaria angustifolia*. This forest is located in a region with no dry season and on landscapes with a strong altitudinal gradient (~600–1600 m). According to Reis et al. (2014), Araucaria Forest has been subject to chronic disturbances since pre-Columbian colonization. Therefore, the authors considered it a cultural landscape. In the middle of the last century, the natural forest was severely affected by the predatory exploitation of timber species. After logging restrictions were imposed, Araucaria Forest was subject to chronic anthropogenic disturbances, such as the extensive cattle ranching, which is a common occurrence in the region (Sevegnani et al., 2012).

This study aimed to investigate regional variations in the demography of the tree component of Araucaria Forest in response to climate, soils, landscape, forest structure, and chronic anthropogenic disturbances. We tested the hypothesis that forest patch metrics (such as fragment area and proportion of interior area), the presence of cattle, and forest structure (basal area) have greater impacts on the observed tree component dynamics patterns than climate and soil conditions.

2. Materials and methods

2.1. Study area

We obtained forest dynamics data for nine areas in Araucaria Forest from the Labdendro/UDESC database (Laboratory of Dendrology and Phytosociology at the State University of Santa Catarina, Brazil). This region is located in Santa Catarina State, Southern Brazil (Fig. 1, Table 1), and is classified as a Mixed Ombrophilous Forest according to the Brazilian vegetation classification system (IBGE, 2012). All forest fragments except for F3 and F5, were inventoried between 2008 and 2012 and re-inventoried four years after the first inventory. For F3, there was a six-year interval between inventories, and for F5, the gap was three years. The differences in intervals did not affect the interpretation of the results, since they were annualized.

Table 1
Characterization of Araucaria Forest fragments in Southern Brazil in the first (Year-1) and second (Year-2) evaluation periods. SA = total sample area.

Forest fragments	Geographic coordinates	SA (ha)	Year-1	Year-2
F1	28°20′30″ S and 49°44′33″ W	1	2012[a]	2016
F2	27°49′01″ S and 50°15′00″ W	1.26	2010[b]	2014
F3	27°55′44″ S and 50°06′18″ W	0.98	2008[c]	2014
F4	27°47′04″ S and 50°20′44″ W	1	2011[d]	2015
F5	27°48′18″ S and 50°19′59″ W	1	2012[d]	2015
F6	28°04′24″ S and 49°37′12″ W	1	2011[e]	2015
F7	27°51′54″ S and 50°11′11″ W	1	2008[f]	2012
F8	27°51′ S and 50°09′ W	1	2012[g]	2016
F9	27°44′16″ S and 50°28′51″ W	1	2011[h]	2015

The inventories in Year-1 are published in:
[a] Ferreira et al. (2016).
[b] Negrini et al. (2014).
[c] Higuchi et al. (2013).
[d] Guidini et al. (2014).
[e] Marcon et al. (2014).
[f] Higuchi et al. (2012).
[g] Pscheidt et al. (2015).
[h] Higuchi et al. (2014).

All of the forest fragments that were evaluated had similar disturbance histories. Their fragmentation processes began about two centuries ago with the onset of agricultural and livestock activities, and intensified in the 1950s in the form of timber logging during the so called *Ciclo da Madeira* period (Lumber cycle – when Araucaria trees were intensively exploited by regionals sawmills) (Higuchi et al., 2012). Araucaria Forest remnants are currently undergoing a series of chronic anthropogenic disturbances, such as the presence of livestock (F1, F2, F3, F6, F8, and F9). Fragments F4 and F7 have had no cattle for ~20 years, while F5 has been protected from cattle ranching for eight years.

2.2. Data collection and analysis

In the first-year inventory, we sampled each fragment using ~1-ha permanent plots. Each fragment plot consisted of subplots ranging from 200 m^2 to 400 m^2 in area. They were allocated in a systematic- or systematic-stratified form and the distances between them varied

Fig. 1. Map showing the location of the Araucaria Forest fragments in the study area of Southern Brazil.