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Integrating plant richness in forest patches can rescue overall biodiversity in human-modified landscapes

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A B S T R A C T

The substitution of natural ecosystems with agriculture has led to the establishment of human-modified landscapes globally. In some tropical regions, this process is decades-old, allowing for the study of the effect of such modifications on the remaining biodiversity. However, unlike forest fragments inside regions with extensive primary coverage, the conservation value of ecosystems embedded within intensive farming, i.e., the anthropogenic matrices, has long been ignored, as have the effects of the landscape on such disturbed forest communities. Since the degradation process is predicted to cause the collapse of these fragmented forests, we can choose either to neglect them or to attempt the reversal of the degradation process for biodiversity conservation. Here we investigated the possible influence of landscape predictors on numerous plant species and on the relative proportions of different functional groups. Our results revealed that the richness found in human-modified landscapes had significantly more species than the protected reserves (+90%). The distribution of species suggested that any forest patch is likely to harbour a rare species. Generalised linear models and quantile regressions showed that forest cover and connected area influences the persistence of pioneer species and non-pioneer species of the canopy and zoochorics, with the latter also depending on slope. Rarefaction analysis revealed that natural remnants retain many species, even in sites with less than 20% forest cover. The presence of many zoochoric and non-pioneer canopy species may indicate a qualitative aspect to support conservation–restoration efforts. These results indicate that the current strategy, which is limited to the preservation of biodiversity in public conservation reserves, should be reconsidered and should include smaller remnants of the natural ecosystem in a regional context and adopt large-scale restoration strategies to preserve the species pool.

1. Introduction

Conservation studies of forest ecosystems have traditionally been conducted in tropical regions with extensive natural forest cover, particularly primary forests (Gibson et al., 2011; ter Steege et al., 2013). Such studies have also been conducted in wildlife permeable landscapes with large habitat areas; these constitute a favorable scenario for ecological processes in the remaining forest patches (Norden et al., 2009; Pardini et al., 2009). However, human-modified landscapes often house numerous relatively small remnants of ecosystems that deserve a closer look. These ecosystems can be of great importance for the conservation of soil and water resources (Ehrlich, 2008; Neary et al., 2009; Rey Benayas and Bullock, 2012; Zhang et al., 2001). Moreover, they may harbour important gene pool sets, and if properly protected, can contribute to the conservation of biodiversity (Chazdon et al., 2009b; Tscharntke et al., 2012) by preventing the mass extinction of species (Wright and Muller-Landau, 2006), as well as contributing to ecological restoration (Krauss et al., 2013; Rodrigues et al., 2009; Tambosi et al., 2014). Furthermore, secondary forests are important for the global carbon cycle (Martin et al., 2013; Pan et al.,

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2011; Poorter et al., 2016), as even small remnants of ecosystems will take on increasing importance once the current global network of reserves for conservation becomes insufficient to effectively offset predicted global climate changes (Lee and Jetz, 2008; Putz et al., 2001).

As the result of extensive fragmentation and the limited areas of the remaining patches, a large number of tropical forest ecosystems are threatened, especially since these are highly disturbed (Arroyo-Rodríguez et al., 2013; Solar et al., 2015; Turner and Corlett, 1996). The conservation value of these remaining forest patches varies with the type of species present, since many are naturally restricted to mature forests because they depend on environmental conditions found basically in conserved ecosystems (Wright, 2005; Oliveira et al., 2008); their presence may depend largely on the intensity of the disturbance of the surrounding agricultural matrix (Sodhi et al., 2010). Even though many of the landscapes in tropical regions are dominated by agriculture, frequently monocultures, and natural remnants are often disconnected (Chazdon et al., 2009a; Tabarelli et al., 2010)– the ecosystems have not yet become classical secondary forests (Barlow et al., 2007; Van Breugel et al., 2013). They may be declining old-growth forests, with a vegetation structure still containing elements resistant to fragmentation, such as long-lived trees (Metzger et al., 2009; Farah et al., 2014). Although the negative impacts of habitat loss in landscapes dominated by monocultures on biodiversity are clear (Immerzeel et al., 2014; Karp et al., 2012), secondary or old-growth remnant forests can still preserve an important and often overlooked richness, maintaining much of the regional flora and fauna (Arroyo-Rodriguez et al., 2009; Dahal et al., 2014; Dent and Wright, 2009). In regions with only small amounts of native forest cover, these remaining forests should be considered in policies for conservation, not only for their richness, but also their potential role in reducing isolation by serving as habitat bridges in the formation of a network of functionally connected areas, stepping stones assisting in the movement of fauna (Boscolo et al., 2008; Fischer and Lindenmayer, 2002; Martensen et al., 2012; Mueller et al., 2014). If all remnants smaller than 200 ha are considered, the mean isolation of remnants would decrease from over 9112 m to less than 1344 m (Ribeiro et al., 2009).

Many of the forest remnants surrounded by monocultures should be actively conserved because they provide key environmental services to society, especially when they are located in densely populated areas. The Brazilian Atlantic Forest is one example of a biome that has suffered intense pressure from human occupation. Approximately 88% of the original forest area has been lost, and nature reserves protect only 2.6% of it (Soares-Filho et al., 2014). Moreover, more than 80% of the remaining forest patches are smaller than 50 ha (Ribeiro et al., 2009). Indeed, large remnants of the Atlantic Forest are rare, and conservation of biodiversity will only be possible if these small- and medium-sized forest remnants can be protected and restored.

The massive changes suffered by forest remnants of tropical ecosystems have gradually led to their disruption and a decrease in the number of individuals of different plant species, especially late successional and very large-fruited trees (Karp et al., 2012; Magnago et al., 2014; Oliveira et al., 2008). A similar loss has been observed for animals of the various trophic levels (Canale et al., 2012; Gibson et al., 2013; Terborgh et al., 2001), although the true extent of such alterations in small patches is unknown. These changes can be viewed as a track record of disturbances that will eventually lead to the collapse of ecosystems (Rietkerk et al., 2004). In fact, ecosystems with low intactness have traditionally been ignored in conservation policies (Newbold et al., 2016). However, the investment in their restoration through adaptive management may be able to reverse the environmental changes, thus promoting the conservation of biodiversity and the provision of environmental services.

Many studies recommend the priorization of conservation or restoration only of those ecosystems that meet a minimum landscape natural cover criterion (Tambosi et al., 2014), often considered to be a minimum of 30% of the forest cover in a landscape in order to avoid the extinction of animal and plant species (Banks-Leite et al., 2014; Lima and Mariano-Neto, 2014), although Muylaert et al. (2016) report the decline of bat richness at such a low threshold. Such an approach can cause environmental decision makers to recommend the abandonment of numerous natural remnants which are considered useless for conservation, thus leaving them to continue on their course to collapse.

The effects of landscape attributes on fauna have been extensively studied for birds (Banks-Leite et al., 2014; Estavillo et al., 2013; Magioli et al., 2015; Martensen et al., 2012). However, little is known about the relationship between landscape and the species and functional groups of plants in forest remnants, yet there is a lack of studies considering the variability of ecosystem descriptors (Karp et al., 2012; Mühlner et al., 2012). Most of the studies which do exist have focused on plots within large, well conserved areas (Gibson et al., 2011; ter Steege et al., 2013). Rarely is the relationship between landscape and plant diversity studied within highly fragmented areas, where the forest cover and patch size are reduced, and where isolation and edge effects are more severe (Magnago et al., 2014; Rodríguez-Loinaz et al., 2012). These natural remnants are not necessarily a lost cause, however, although their ability to contribute to conservation and to provide environmental services will depend on their structural integrity and biodiversity (Ferraz et al., 2014; Honey-Rosés et al., 2013; Lopes et al., 2009). The present study was designed to promote the understanding of the effects of landscape on the richness of tree-like plants and their proportions; aspects considered included mode of seed dispersal and ecological category. An attempt was made to answer the following questions for a monoculture matrix region: (1) What is the influence of landscape structure on plant richness and the proportion of species of different ecological groups? (2) Is the plant richness different for sites with different amounts of forest cover? (3) Does the regional pool of species, distributed in several small disturbed patches, increase total richness above that provided by large areas of protected forest? We hypothesized an increase in overall richness, especially that of zoochoric species, non-pioneer species of the canopy, and understory species, with an increase in the forest coverage of the site, even if it has been subjected to anthropogenic influences; we further hypothesized that it would increase with connectedness. This is one of the few studies evaluating the role of remaining fragments in the conservation of plant diversity in highly fragmented landscapes dominated by intensive agriculture for many decades.

2. Material and methods

2.1. Study site

The study was conducted in the domain of a seasonal semideciduous forest of the Atlantic Forest in a broad area of the interior of the state of São Paulo in Brazil (Fig. 1), an area with Cwa climate (Alvares et al., 2013) and altitudes of 400–550 m above sea level. The studied landscapes cover 300 km in the N-S direction and 400 in the W-E direction. The average distance between sites and reference reserves is 140 km. Since the colonial period, native forests have gradually given way to monoculture plantations –mainly coffee in the past, and sugarcane at present. This has led to intense devastation of the landscape since 1850. The first forest inventories estimated a loss of more than 80% of the forests by the 1950s