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Original Articles

Woody species diversity as an indicator of the forest recovery after shifting cultivation disturbance in the northern Amazon

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ABSTRACT

The Amazon region harbors the most important tropical forest in the world. However, its biodiversity is seriously threatened due to land-use change. Here, we evaluated changes in tree species diversity and composition after shifting cultivation in the northern Amazon forest, Amazon state, Venezuela, through a chronosequence approach. We selected three sites over a 12 km^2 extension of an old-growth forest matrix with secondary forest patches of different stand ages. A total 45 plots (each having 20 × 50 m = 1000 m^2) were established. At each site, woody plant diversity and the composition of trees having diameter ≥ 5 cm were assessed in four secondary forests (5, 10, 15, and 20 years old stands after shifting cultivation) and in one old-growth forest (> 100 years old), and three plots were established in each forest type. Species richness and dissimilarity pairwise beta-diversity metric were calculated for paired plots among different forest types. We analyzed differences in diversity among the four successional stages and the old-growth forest using individual-based approach. Additionally, multivariate analyses were performed to examine differences among the sampled forest areas in terms of species composition along soil gradient. Species richness showed consistently increasing pattern along the succession to old-growth forest. Species richness in the old-growth forest was up to three times higher than in forests at early successional stages. Richness recovery rate in the 20-years old secondary forest two decades after the abandonment of shifting cultivation was on average equal to 70% of the species richness in the old-growth forest. In contrast, the recovery of species composition reached an average 25% in relation to the old-growth forest during the same period. Our results show that the effect of stand age and environmental drivers (i.e., soil properties) determine species diversity along succession. The environmental heterogeneity between successional stages can be analyzed by the differences in floristic composition and beta diversity observed among the analyzed plots. For that reason, we presume that beta diversity is the major determinant of species richness in secondary forests. The proposed approach contributes to the sustainable management of forest communities because it allows estimating the woody species diversity recovering after shifting cultivation disturbance across successional stages.

1. Introduction

The Amazon basin is one of the most extension of continuous tropical forests, harboring about 11% of the global tree species (Cardoso et al., 2017). However, the biodiversity of Amazon old-growth forest (OG) is seriously threatened due to land-use changes such as agricultural expansion (Barlow et al., 2016; Lewis et al., 2015). Shifting cultivation is a type of agricultural system which consists of deforesting small areas (through slash-and-burn) of OG or secondary (growth) forest (SG) to establish agricultural crops for short periods of time (i.e., 2–3 years), and the subsequent abandonment of the land usually leads to the reduction of soil fertility (Arroyo-Kalin, 2012; D'Oliveira et al.,

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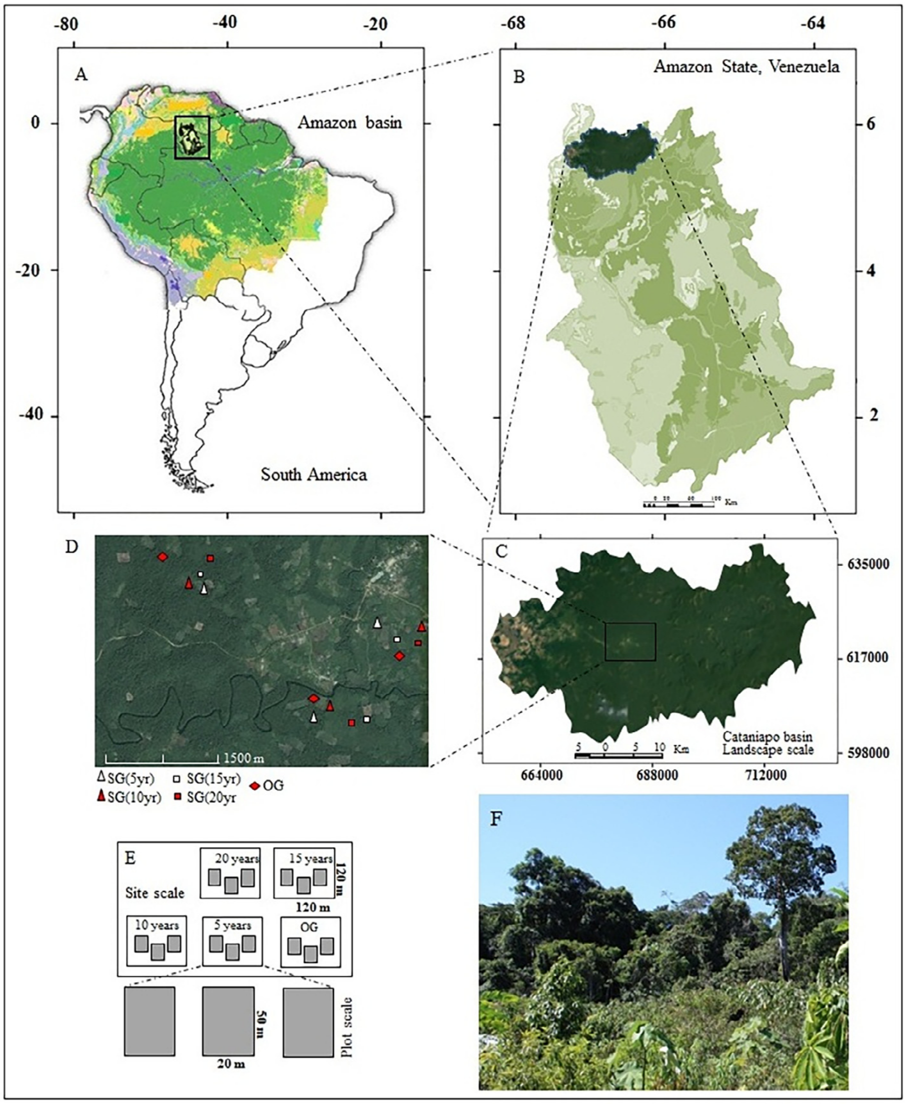

Fig. 1. Map and images of study area. Location of study region in the Northern Amazon forest (black square), in South America (A). Map of the Amazon region indicating the Cataniapo basin, in the Northern Amazonas State, Venezuela (B). Map of the Cataniapo basin indicating the location of the study area, between Gavilán and Sardi communities in the Cataniapo basin (C), showing distribution of areas sampled secondary forest (color symbols). Satellite image of the study area showing some secondary forest patch in Gavilán (D). We stratified the sampling of the three sites within one forest landscape from Gavilán (E). Early second growth forest after shifting cultivation (F).

2011). Shifting cultivation is also one of the most common forms of land use that contribute to the loss of biodiversity in Amazonas (Jakovac et al., 2015; Villa et al., 2017). Despite that, SG re-growing after the abandonment of agricultural systems (e.g., shifting cultivation) still represent a reservoir of biodiversity (Chazdon, 2014; Gibson et al., 2011), as these forests contain more than half of the global forest area (FAO, 2010). In fact, secondary succession has been demonstrated to be a feasible method of great importance to restore forests with high floristic diversity, especially when compared with other methods with which a limited number of woody species can be employed (e.g., Palomeque et al., 2017).

The process of diversity recovery during secondary succession depends on several environmental drivers, which may largely determine its trajectory (Arroyo-Rodríguez et al., 2015; Meiners et al., 2015). However, in human-modified landscapes, the land-use history (Klanderud et al., 2010; Zermeño-Hernández et al., 2015), intensity and duration (Guariguata and Ostertag, 2001), and the time since abandonment (Pascarella et al., 2000) are some of the most important anthropogenic drivers in tropical forests (Chazdon, 2014). For instance, the changes in land use (e.g., agricultural expansion) may have significant impacts on ecological drivers (e.g., dispersal limitation, biotic homogenization), which consequently have direct effects on species diversity (Barlow et al., 2016). In this context, understanding how the species diversity and composition of SG recover along different chronosequences of succession in human-modified landscapes represents an important challenge to improve the methods of forest conservation, restoration and management in the Amazon basin (Villa et al., 2017).

Most of the previous studies on the secondary succession in tropical forests have addressed the changes in species diversity and composition after shifting cultivation (Chazdon, 2014; Guariguata and Ostertag, 2001) based on the chronosequence approach, aiming to establish comparisons between plots with different regeneration times (Chazdon et al., 2007). Studies comparing SG and OG have suggested that areas undergoing regeneration may harbor a higher diversity of tree species due to the maximized coexistence of fast-growing pioneer species and more competitive canopy species (Bongers et al., 2009; Mwampamba and Schwartz, 2011). The ecological theory on the mechanisms of maintenance of species diversity in relation to the disturbance intensities (e.g., Intermediate Disturbance Hypothesis: Connell, 1978) supports this observation. Indeed, the constant species turnover that takes place along succession (beta diversity) is one of the most important mechanisms that maintain local species diversity (Arroyo-Rodríguez et al., 2015; Meiners et al., 2015). There is also some evidence that the biodiversity resilience in SG may be high because species richness can quickly recover to mature forests during succession (e.g., Norden et al., 2009). On the other hand, recovering species composition might take centuries depending on the local environmental conditions