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Successional processes in agricultural mosaics in the eastern Amazon

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ABSTRACT

Most tropical landscapes are mainly composed of dynamic mosaics involving multiple land uses. Different histories of land use management can lead to different successional paths. The aim of this study was to determine if there is a successional floristic gradient related to land use types and how these gradients change across three rural mosaics in Eastern Amazon. We also investigated what are the indicator species across mosaics and land use types and how they change through succession. Five sampling points were established in nine family farms at each mosaic. A detrended correspondence analysis was used to reveal the successional gradient. A multivariate regression tree was used to analyze differences in floristic composition between mosaics and land uses. Floristic similarity between land uses formed successional gradient at the mosaics, in which agricultural land uses represent the early stages of secondary succession and forests represent more advanced stages. Total number of species and total number of shade-tolerant species were correlated with advanced successional stages in all mosaics, but pioneer trees were also correlated with advanced stages in fragmented mosaics. Each mosaic had a distinct successional series due to different management approaches. Where the matrix was mainly composed of forest fragments and the human intervention period was shorter, land use types were more similar to one another as they were grouped into fewer successional stages. Thus, the floristic similarity between land use types appears as an indicator of successional advancement across the mosaics and help determine the regenerative capacity of those areas.

1. Introduction

Understanding the successional process is important for the advancement of theoretical ecology as well as for the development of conservation programs and the exploitation of biological resources (Finegan, 1984; Meiners et al., 2015; Arroyo-Rodríguez et al., 2017). Current knowledge about succession in the tropical region derives primarily from chronosequence studies in secondary forests (Chazdon, 2012). In recent years, several studies have monitored forest regeneration and successional processes over time (Chazdon et al., 2007; Lebrija-Trejos et al., 2010; Mora et al., 2015; Rozendaal and Chazdon, 2015). These studies have become increasingly necessary in tropical landscapes that today are mainly composed of dynamic mosaics involving mature forest remnants and secondary forests of different ages that are also connected to agricultural areas such as croplands and pastures (Van Breugel et al., 2013).

These different land use types result from family farm production processes in rural areas. The processes are established in a successional sequence where land use is traditionally initiated by slashing and burning of the forest to cultivate annual and/or temporary crops or to establish pastures. Succession starts while these cultivations are still active, because even though the effect of clearing on dense rainforests drastically reduces the initial species richness, a large number of forest woody species succeed in maintaining themselves after the clearing, and they may represent more than half of the species present in croplands or pastures (Mitja et al., 2008; Miranda et al., 2009; Mitja and Miranda, 2010). Over time, agricultural areas become unproductive with high maintenance costs due to the loss of soil fertility and further invasion of woody and/or herbaceous plants, and consequently, these areas are abandoned where the natural regeneration process is advanced, resulting in fragments of secondary forest among crops. Thus, it is essential to consider the different land use types present at the landscape scale to understand the successional process in rural mosaics (Meiners et al., 2015).

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At the landscape scale, succession will be affected by factors such as the history of land use, amount of forest cover, matrix characteristics and landscape connectivity (Arroyo-Rodríguez et al., 2017). These factors interact with one another and can lead to different successional paths and hence divergent secondary forests with their own unique vegetation structure and richness (Chazdon, 2008a; Chazdon et al., 2010; Meiners and Pickett, 2011). Studies have also repeatedly shown that even in abandoned areas with the same fallow period, soil type and climatic conditions, succession does not necessarily follow a single, predictable path leading to the state of the original forest (Chazdon et al., 2007; Norden et al., 2011, 2015). Within the same landscape, some areas may experience rapid rates of regeneration while others exhibit irregular courses and/or slow regeneration rates (Norden et al., 2011, 2015; Cole et al., 2014; Jakovac et al., 2015). Different approaches to management and duration of the crop period may lead to different rates of regeneration as well as to differences in floristic composition over the successional process (Mitja et al., 2008).

Seed dispersal, seed germination and seedling recruitment are affected by different interconnected controlling factors, such as topography, forest cover in the landscape, isolation and matrix complexity (Laurance et al., 2002; Ewers and Didham, 2006; Arroyo-Rodríguez et al., 2017). Thus, the structure of biotic assemblages inhabiting secondary forest patches in human-modified landscapes is determined by a set of driving forces across multiple scales (Gardner et al., 2009; Tabarelli et al., 2012; Meiners et al., 2015). For plants, these driving forces may represent regenerative barriers that act as dispersal-limiting agents or ecological filters (Tabarelli et al., 2012).

The aim of this study was to analyze the successional process in three rural mosaics of southeast Pará State so that the following questions could be answered: Is there a successional floristic gradient related to land use types? How these gradients change across mosaics? What are the indicator species across mosaics and land use types and how they change throughout succession?

2. Materials and methods

2.1. Study area

The study was conducted in 2008 at three rural communities with small family farms in the settlements of Palmares II, Maçaranduba and Travessão 338-S located in southern and southeastern Pará state, Eastern Amazonia, in the region known as the Arc of Deforestation (Fearnside, 2017). Each community was considered as a rural mosaic where forest fragments are adjacent to different land use types. The Palmares II Settlement Project, located in the municipality of Parauapebas, was established in 1996 with farms covering 86 ha on average (n = nine farms sampled). The community of Maçaranduba is located in the municipality of Nova Ipixuna in the Praia Alta-Piranheiras Agricultural-Extractivist Settlement Project. This community was established in 1994 and each farm covers 71 ha on average (n = 9). The community of Travessão 338-S is located along the Trans-Amazonian Highway in the municipality of Pacajá. It was established in 2001 with farms covering 26 ha on average (n = 9) (Fig. 1). These three communities were also already studied by Oszwald et al. (2011), Costa et al. (2012), Grimaldi et al. (2014), Marichal et al. (2014), Do Vale et al. (2015) and Lavelle et al. (2016). The dominant primary vegetation is tropical rain forest, and the average annual temperature in the study area is approximately 26 °C. The climate is classified as super humid in Parauapebas, humid tropical in Pacajá and rainy tropical in Nova Ipixuna, according to the Köppen classification.

The studied farms are marked by a recent change in landscape dynamics, featuring mosaics with different land covers, such as pastures, croplands, secondary forests and others. However, the three areas experienced different dynamics. An analysis of the structures of the landscapes in 2007 and its dynamics between 1990 and 2007 was presented by Oszwald et al. (2011), including a location map of the studied farms and Landsat images corresponding to land cover in 2007. The community of Palmares II presents a very fragmented agricultural landscape, with many pastures and croplands, in addition to the presence of recent ground fires in remaining forest areas. The whole area is well served by roads, but the distance between the residential area (Village of Palmares II) and the crops location is the main factor explaining the degree of human impact. Maçaranduba is the oldest community and presents a primarily agricultural landscape, composed by many patches of pastures in different stages of progress. Secondary forests were formed after the abandonment of the croplands and the remaining forests are relics in riparian zones or in areas of difficult access. The landscape is characterized by a very fast and intense transition mainly from forest to pastures. Travessão 338-S is the community most recently affected by deforestation. The first human intervention began in early 1990 and the conversion from forests to agricultural land was still at early stages in 2007. The farms were primarily forested or composed of large forest patches, which characterizes the forest matrix.

2.2. Experimental design

A socio-economic survey carried out with 50 small family farmers helped define which farms were most representative of each mosaic (De Sartre et al., 2011). Nine farms were selected in each rural mosaic. Five sampling points were established at each farm for the inventory of vegetation, resulting in 45 sampling points per mosaic. The points were equally spaced along the longest diagonal of the farm, using a map. Thus, the distance between the points was equal to 1/6 of the diagonal length, which varied according to the farm size (between 200 and 400 m on average). Because the points were systematically spaced along the diagonal of each farm, they were not selected based on the type of land use. Thus, it was assumed that the vegetation cover at the points reflected the land use types prevailing in each studied mosaic.

At each sampling point, the vegetation was sampled for three strata. A plot of 10×50 m (500 m^2) was established for the upper stratum inventory (individuals with DBH ≥ 10 cm), a subplot of 5×50 m was established for the middle stratum (individuals with DBH < 10 cm and height ≥ 2.0 m) and finally, 10 subplots of 1×1 m were regularly distributed in the center of the plot for the lower stratum inventory (individuals with 2.0 m > height ≥ 10 cm).

We identified nine types of land use in the three studied rural mosaics. The Palmares II mosaic is the only one that has burned forests, does not have conserved forests and has the largest number of annual crops. Maçaranduba has the largest number of pastures, while Travessão 338-S has the largest number of forests and is the only one with tree plantations (Table 1).

The species were classified into groups based on their life form (herb, liana, shrub, palm or tree) as in Brower et al. (1998), and their shade tolerance guild (pioneer or shade-tolerant). Pioneer species occur in forest gaps and open areas, usually producing many seeds that are viable for long periods on the forest floor. This group also includes secondary species, which are absent from the forest but may establish quickly in deforested areas (Puig, 2008; Mitja et al., 2008). Shade-tolerant species are those that have seeds that can germinate and establish in the shade. Young plants of this type are thus commonly found beneath the canopy but can occasionally be seen in open areas (Swaine and Whitmore, 1988).

Previous species identification was performed by a parataxonomist and was confirmed by comparison with specimens in the Herbarium João Murça Pires located at the Museum Paraense Emilio Goeldi. The plants were classified in accordance with the Angiosperm Phylogeny Group III system (APG III, 2009). The few unidentified individuals (2, 5 and 6% of the individuals from Palmares II, Maçaranduba and Travessão 338-S, respectively) were excluded from the analysis.

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