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High plant species richness in monospecific tree plantations in the Central Amazon

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ABSTRACT

Because forest plantations cover an extensive area worldwide, they play an important role shaping current biodiversity conservation policies. This study evaluated plant species richness in the regenerating forest community beneath five 35-year-old homogeneous forest stands consisting of indigenous terra-firme species (*Simarouba amara*, *Dipteryx odorata*, *Bagassa guianensis*, *Jacaranda copaia* and *Dinizia excelsa*). These data were compared to adjacent primary forests in the Manaus region, Amazonas state, Brazil. These plantations are among the oldest native tree plantations of the Brazilian Amazon. All studied stands showed species richness near that of the primary forest, with the single exception being *J. copaia*. The relationship between species composition and the environmental variables was studied by canonical correspondence analysis (CCA). The CCA yielded correlations that were validated by a permutation test between species composition and canopy openness, nitrogen content, pH, base saturation and soil aluminum content. Our results showed that long standing homogenous plantation stands can provide high levels of density and species richness of the understory, comparable to those found in the surrounding primary forest. This finding reinforces the value of anthropogenic landscapes for conserving biodiversity.

1. Introduction

Deforestation is the major cause of biodiversity loss and is one of the most important environmental preoccupations in the world. Areas covered by primary forests have decreased, while secondary forests and plantations have shown continuous expansion (Wright, 2005; FAO, 2010). Although Brazil includes extensive areas of planted forests, these forests represent only a small fraction of the total forested and altered agricultural areas in the country. Nevertheless, one of the current policies of the Brazilian government is to increase planted forest areas (PNF, 2000), especially in degraded and/or abandoned areas. Moreover, the Brazilian forest code only allows primary forest suppression if an entrepreneur also provides a new forest plantation as a "green credit" for this environmental damage (Federal Law nº12.651/2012).

Primary tropical forests have complex ecosystems and dynamics: they are multi-stratified and have high biodiversity. Although planted forests are expected to have lower biodiversity compared to natural forests, their biodiversity may be high relative to degraded areas and areas used for crop production and pastureland. Planted forests can also provide favorable habitats for a variety of animal and plant species. In this context, several authors have suggested and debated that these areas should be incorporated into the conservation scenario (Carnus et al., 2006; Cyranoski, 2007; Brockerhoff et al., 2008; Bremer and Farley, 2010).

There are several indicators of biodiversity in forest plantations, including the presence of birds, bats, invertebrates, mammals and plants. Among these indicators, vegetation is less studied (Stephens and Wagner, 2007). A plethora of studies have shown the role of forest plantation establishment in facilitating succession processes (Silva Júnior et al., 1995; Otsamo, 2000; Parrotta and Knowles, 2001; Yirdaw, 2001; Senbeta et al., 2002; Cusack and Montagnini, 2004). The catalyzing effect of these plantations occurs as a result of improved structural vegetation complexity overtime, resulting in altered microclimate conditions; an increase of the litter layer, soil structure and fertility; the attraction of seed dispersers; and the reduced proliferation of ferns and grasses (Lugo, 1997; Parrotta et al., 1997a; Montagnini, 2005). In general, planted tree species do not regenerate under their own canopy or becomes less dominant at the site, allowing colonized species to reach the canopy and reproduce. This finding has been observed pantropically (Lugo, 1997).

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Several factors may influence the regeneration of species in the plantation understory. The richness and diversity of regenerating species is greatly influenced by the species that are planted (Parrotta et al., 1997a; Firn et al., 2007; Duan et al., 2008; Bremer and Farley, 2010), and some species (*sensus* Connell and Slatyer, 1977) may better promote the growth of colonizing species beneath their canopy. Several authors have suggested that mixed species plantations more efficiently promote natural regeneration than single species plantations (Lamb, 1998; Carnevale and Montagnini, 2002; Duan et al., 2008). Older plantations have higher biodiversity than younger ones because their structural complexity increases overtime (Parrotta et al., 1997a; Kanowski et al., 2003; Carnus et al., 2006; Barbosa et al., 2009). Another important factor that influences the establishment of regenerating species in the plantation understory is the distance of the plantation from the forest matrix: the nearer the plantation is to the primary forest, the greater the chance of colonization (Lamb, 1998; Carnus et al., 2006; Brockerhoff et al., 2008; Bremer and Farley, 2010).

There is a scarcity of studies focusing on natural regeneration in forest plantations in the Brazilian Amazon, primarily because there are few reforested areas in the region. Therefore, the present study will collect important information of relevance to recent governmental incentives for plantations on private land. A 10-year study program in ecological restoration in the Eastern Amazon has shown that native species stands promoted regeneration more efficiently than those with exotic species (Parrotta et al., 1997b; Parrotta and Knowles, 2001). From a broader perspective, Barlow et al. (2007) observed an increasing gradient of plant species richness, ranging from forest plantations (4–6 years old), to secondary forests, to the primary forest.

The majority of studies on the natural regeneration of forest plantations were carried out in young stands (Silva Júnior et al., 1995; Parrotta et al., 1997b; Parrotta and Knowles, 2001; Cusack and Montagnini, 2004; Barlow et al., 2007). In this study, we investigated natural regeneration in five, 35 year old pure forest stands that included species native to the Amazon region. Currently, this study is unique in old stands. Our objectives were the following: (1) verify if homogeneous forest plantations can harbor levels of species richness similar to that of the adjacent primary forest, (2) investigate differences in species richness among plantations of different species, and (3) evaluate the relationship among natural regeneration and environmental variables of interest.

2. Materials and methods

2.1. Study site

This study was carried out at the Tropical Silviculture Experimental Station (TSES) of the National Institute of Amazonian Research (INPA), 02°35′51.28″S; 60°02′10.57″W, Manaus, Amazonas, Brazil (Fig. 1). The soil varies from yellow clayey latosols (oxisol) to sandy soil (Ranzani, 1980; Chauvel et al., 1987). The climate is tropical rainy, with an annual mean temperature of almost 26.6 °C. The relative humidity and precipitation vary from 75% to 86%, and 1750–2500 mm, respectively, with an annual average of 2440 mm (Ribeiro and Adis, 1984).

Here, we investigate five pure forest plantations of species native to the Amazon: *Simarouba amara* Aubl., *Dipteryx odorata* (Aubl.) Willd., *Bagassa guianensis* Aubl., *Jacaranda copaia* (Aubl.) D. Don and *Dinizia excelsa* Ducke (Table 1). In the 1970s the

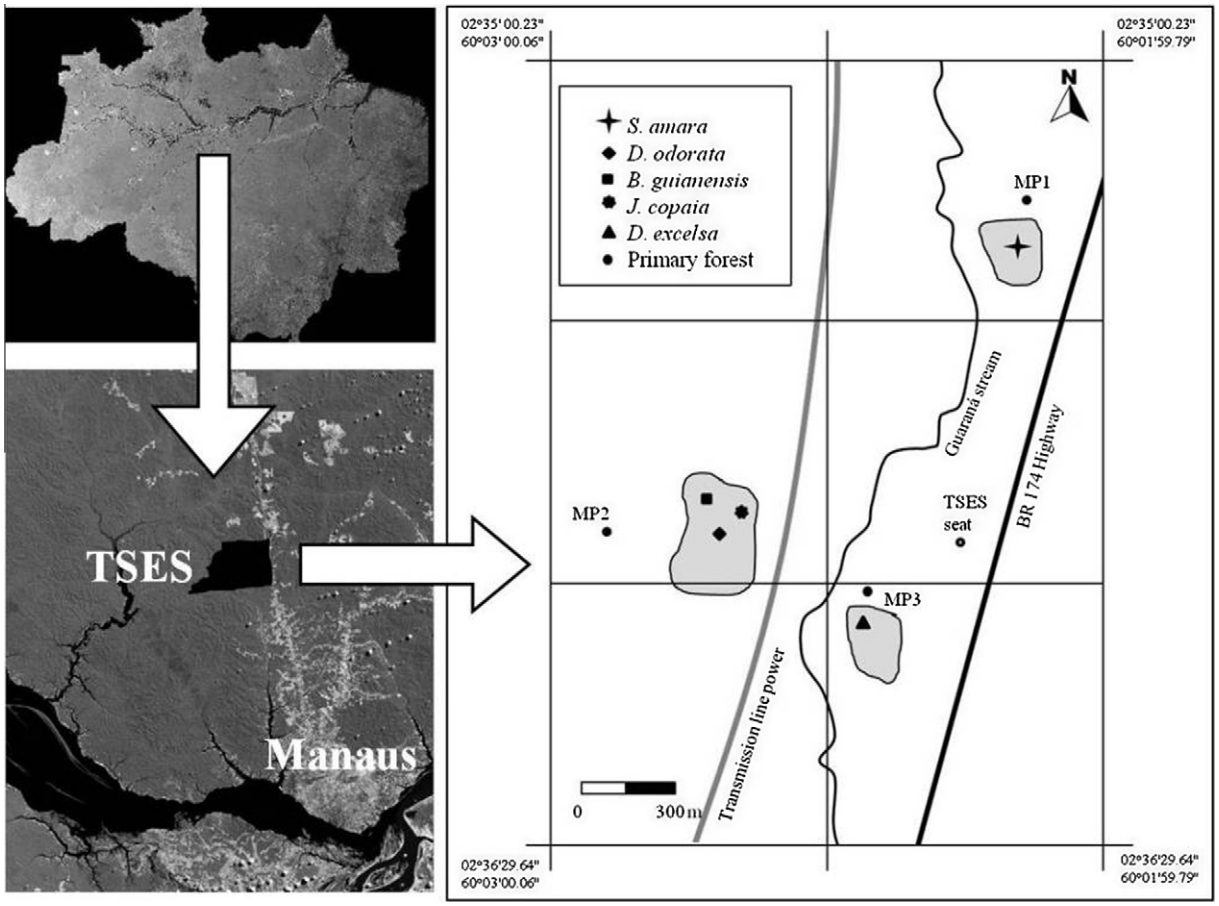

Fig. 1. Plantation and primary forest sites in Tropical Silviculture Experimental Station (TSES), Manaus, Brazil.