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Management practices may lead to loss of arbuscular mycorrhizal fungal diversity in protected areas of the Brazilian Atlantic Forest

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A B S T R A C T

The symbiotic arbuscular mycorrhizal (AM) fungi are among the ecologically most significant organisms in terrestrial ecosystems, but little is known about how soil AM fungal community composition responds to conservation management and different degrees of human impact on natural ecosystems. The objective of this study was to evaluate effects of the management practices on the AM fungi community structure in protected areas of the Atlantic Forest in Northeast Brazil. During two seasons we assessed AM fungal diversity and mycorrhizal root colonization status in five strict-protected and five sustainable-use areas along a 900 km transect. The sampling effort was sufficient to recover more than 85% of the AM fungal species present in the protected areas. Fifty-six AM fungal species and morphotypes were identified. Most species belonged to Glomerales and Gigasporales, but all orders of Glomeromycotina were registered. Species diversity and mycorrhizal colonization were significantly higher in the strict-protection management areas, though the areas had the same richness and spore density. Seasonality and spatial distances did not affect the AM fungal community composition. Our results show that the conservation management, vegetation and soil characteristics are important local factors influencing AM fungal communities. This work provides a better understanding of AM fungal community structure in natural ecosystems and provides insight into distribution patterns at a broad landscape scale.

1. Introduction

Brazil's Atlantic Forest is considered one of the 35 global hotspots of biodiversity. The forest has a rich fauna and flora exhibiting considerable endemism, ranging from >8000 endemic plant species to >650 endemic vertebrate species (Myers et al., 2000), but is threatened by increasing human activities (Mittermeier et al., 2011). At present, only about 2% (19,427 km^2) of the Atlantic Forest on the Northeast coast of Brazil remains in pristine conditions (Ribeiro et al., 2009), but the highly fragmented forest continues to provide important ecosystem services, such as climate regulation, nutrient cycling, water supply, electricity production, among others (Joly et al., 2014).

The concept of protected areas (PAs) has been the main strategy to protect the remaining habitats and species (Bruner et al., 2001). In Brazil, protected areas are classified into strict-protected and sustainable-use conservation reserves (categories I–VI) (IUCN, 2016). In strict-protected areas the main objective is to preserve biodiversity, allowing only the use of ecosystem services, while areas of sustainable-use allow exploitation of some natural resources which renders biodiversity protection a secondary goal (Rylands and Brandon, 2005). Although most of the protected areas suffer from political, economic and demographic pressure, the areas where sustainable-use is allowed, may face an even greater challenge as the majority of the areas are located in the vicinity of large urban centers. Thus the remaining fragments continue to be

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under pressure from human occupation, harvesting of firewood, illegal logging and invasive species (Tabarelli et al., 2010).

Understanding how communities respond to habitat fragmentation, and to different conservation management, still imposes a challenge (Magnago et al., 2014; Vályi et al., 2016). Species richness and abundance of several taxonomic groups have been shown to be negatively affected by anthropogenic environmental changes (Santos et al., 2008; Docile et al., 2016), and long-term impact may even result in extinctions at the regional scale, as recorded for 33.9% of tree species in Brazilian Atlantic Forest (Silva and Tabarelli, 2000). The ability of plants to persist and develop is also affected by belowground microbial relationships in the rhizosphere (Rosier et al., 2016). The most significant and best studied symbiotic interaction between plants and fungi is arbuscular mycorrhiza (AM) (Oldroyd, 2013). In this symbiosis, the fungi increase plant nutrient uptake and in return receive carbon (C) from the plants (Smith and Read, 2008).

Arbuscular mycorrhizal fungi play a key role for the ecosystem services provided by plant communities by increasing plant tolerance to drought, salinity, heavy metals' pollution, mineral nutrient depletion and biotic stresses as well as increasing soil stability and water retention (Gianinazzi et al., 2010). Diversity and composition of AM fungal communities are also an important determinant of plant community composition and, together with productivity, AMF are considered among the ecologically most significant organisms in terrestrial ecosystems (Smith and Read, 2008). Studies in tropical forests have recorded 123 AM fungal species representing approximately 42% of the total number of the species described in Glomeromycotina (Öpik and Davison, 2016) (but see more details in Table S1).

The ecological and evolutionary factors that shape AM fungal communities are spatiotemporally dependent and knowledge of both spatial and temporal patterns are fundamental to understand AM fungal community dynamics. Nevertheless, most studies of AM fungal communities are based on data obtained at relatively small spatial scales and there is a need for studies considering larger spatial scales and standardized sampling time. This will provide more robust information on the relative influence of environmental filtering, dispersal limitation and environmental drivers affecting AM fungal community structure.

In this study, we analyzed AM fungal diversity and root colonization status in protected areas under different management practices along with a 900 km transect on the Brazilian Northeast coast during the wet and the dry season. The aim was to test if strict-protected areas, in the Atlantic Forest had higher AM fungal density, diversity and root colonization compared to sustainable-use areas and if it is possible to define AM fungal species that are indicators of management practices of protected areas. Additionally, the sampling allowed us to test if the management practices influence the spatial and temporal characteristics of the AM fungal communities in the Brazilian Atlantic Forest.

2. Material and methods

2.1. Study areas and sampling design

Roots and soil were sampled twice in each of the ten protected areas in the North-eastern Brazilian Atlantic Forest along a 900 km transect (Fig. 1). Detailed information is provided in Table S2, but briefly, parks were created between the 1970s and 2000s and the areas represent *restinga*, semi-deciduous and dense ombrophilous forest formations. The climate is Tropical, according to Köppen's classification, varying between rainforest (Af), monsoon (Am) and dry summer (As) classes (Kottek et al., 2006). Mean annual temperature is 25.5 °C, and annual rainfall ranges from 1000 to 2200 mm. The first sampling took place between September and November 2013 which marked the period with less rainfall (dry season); while the second sampling time, was conducted between June and August 2014 during the period with a peak in precipitation (wet season). In each one of the five strict-protected (SP) and five sustainable-use (SU) areas, four plots of 5 m × 20 m with 50 m spacing between them were laid out in the interior of the fragments to avoid edge effects. In each of the four plots per area, ten soil and root subsamples were collected (0–20 cm depth) and pooled to

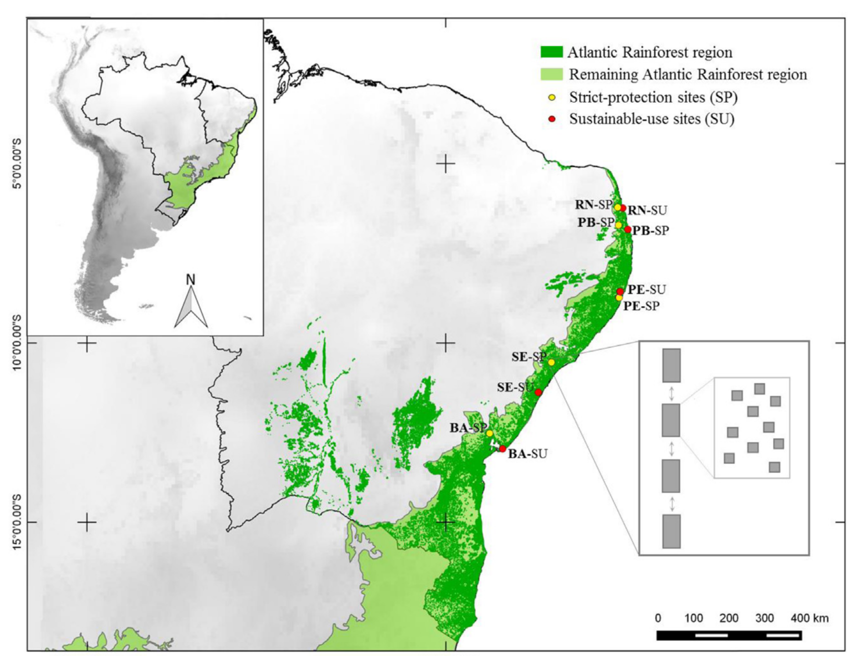

Fig. 1. Map of North-eastern Brazil showing the 10 sampling locations of arbuscular mycorrhizal fungal communities in the remaining Atlantic Forest region (more details in Table S2). The smaller box indicates the sampling strategy used in all protected areas.