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Research Letter

Limited relevance of studying colonization in degraded areas for selecting framework species for ecosystem restoration

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ABSTRACT

The framework species method has been successfully used to restore tropical forests in different parts of the globe. However, establishing experimental plantations for selecting a set of appropriate framework species is extremely time and labor consuming. Here we tested if species performance during colonization of degraded areas could be used to select framework species for restoration programs. We made a survey of the vegetation naturally colonizing a lake margin impacted by bauxite tailings. We followed survival and growth of these individuals during two years and compared their performance with planted individuals of the same species on a restoration project developed nearby. We found no clear relation between species performance during natural colonization and performance when planted in the same substrate. Future studies evaluating performance in the nursery and experimental plantations are still essential for selecting the best framework species and will greatly contribute for restoration of highly diverse ecosystems.

Introduction

Land use changes exert strong impacts on biodiversity worldwide (Geist and Lambin, 2002; Sodhi, 2008). This is particularly true for developing countries, which harbor most of the global biodiversity hotspots (Mittermeier et al., 2004). At the same time, their vigorous economic growth promotes accelerated rates of land conversion. Therefore, developing successful strategies for restoring highly diverse tropical ecosystems are

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urgently needed (Dias et al., 2012; Rodrigues et al., 2011). This is recognized by the Convention of Biological Diversity that has set as one of its 20 targets for 2020 to restore 15% of all degraded habitats in the planet (Mittermeier et al., 2010). However, high diversity poses an additional challenge for ecosystem restoration, as a large number of species needs to successfully establish for recovering the typical structure and function of the system.

The use of framework species might help overcoming this problem (Goosem and Tucker, 1995; Lamb et al., 1997). By planting a restricted number of native species, it is possible to re-establish a multi-layered canopy structure and restore nutrient and carbon cycles. This new basic forest framework will then attract wildlife which can bring seeds and slowly increase forest diversity and functionality. While this method has been successfully used to restore tropical forests in different parts of the globe (Knowles and Parrotta, 1995; Tucker and Murphy, 1997; Wydhayagarn et al., 2009), a critical step is the selection of the appropriate framework species. The selection of framework species usually follows a set of criteria, namely: (i) high survival and growth of sapling planted in the degraded area, (ii) easy propagation by seeds under nursery, (iii) crown architecture to shade out weeds or improve understory environmental conditions and (iv) resistance to specific field harsh conditions (e.g., drought, fire and flooding). The evaluation of these criteria is, however, extremely time and labor consuming as it requires experimental plantations to follow species performance in the field (Elliott et al., 2003).

Alternatively, we suggest that identifying species with high performance during initial colonization in degraded areas could give a first hint of a set of framework species. If species performances during passive and active restoration are correlated, studying natural colonization of degraded areas would provide a cheaper method for selecting framework species as compared to experimental plantations. To test this hypothesis, we studied the natural colonization on an area impacted by bauxite tailings in the Amazon. Our approach was three-fold: first, we made a vegetation survey to identify species colonizing the bauxite tailings; second, we followed survival and growth of the naturally recruited species during two years; and third, we compared the performance of individuals of the same species naturally colonizing the bauxite tailings and planted on a restoration project developed nearby.

Materials and methods

Study site

Our study site comprised an area impacted by bauxite tailings at the margins of Lake Batata (1°30′S, 56°20′W), which is located in the district of Porto Trombetas, municipality of Oriximiná, state of Pará, in the Brazilian Amazon. This lake lies on the right bank of the Trombetas, a clear water river. Clear-water rivers typically have high transparency, low quantity of organic and inorganic suspended material, a pH from low to neutral, low nutrient availability, and are bordered by *igapó* vegetation (see Prance, 1979 for terminology regarding Amazonian flooded forests).

As a result from bauxite mining in the nearby terra-firme forest, tailings were continuously discharged into the Lake from 1979 until 1989. When discharge was halted, ca. 600 ha of lake (ca. 30% of the area of the lake) and marginal *igapó* (flood-prone) vegetation were buried by bauxite tailings. The bauxite tailings consist of red, muddy clay composed basically of iron and aluminum oxides and differ from native *igapó* soil in having a marked compaction, decreased porosity and infiltration capacity and reduced microbial activity (Parrotta and Knowles, 1999). The study site is subjected to eight months of flooding per year. This severe flooding regime represents a major challenge for restoration due to its impact on trees survival and growth.

On the study site, two restoration strategies were adopted. Passive restoration, where plants were allowed to freely colonize the substrate, and active restoration, where saplings of native igapó species were introduced. The areas of passive and active restoration were contiguous and had no differences in substrate, flooding regime and were not subjected to any management except for the sapling introduction in the active restoration area.

Passive restoration

To record the natural colonization of the bauxite tailings, we set up a 1.12 ha grid, consisting of 28 quadrats, each with an area of 20 m × 20 m. In December 2003, we labeled and identified all plants within the grid, which were then measured for height and basal diameter. Diameter of each individual was measured at the closest height of soil level that did not show any stem deformity (e.g., root above-ground expansions). In the following two years, in December 2004 and 2005, all surviving plants were measured again, and newly germinated plants were labeled, identified, measured and added to the list. Growth was calculated as the absolute increase in basal diameter per year. Since we found out that all newly germinated plants sampled in the second and third years had a basal diameter equal or lower than 0.5 cm, we classified all such plants, including those sampled in 2003, as regenerants. Plants with values higher than 0.5 cm were classified as recruits.

We calculated the importance value (IV; Müller-Dombois and Ellenberg, 1974) for the recruited plants of each species for all years. This is a measure of species dominance, which is given by the sum of relative frequency, density and basal area. We considered the species that accounted for up to 75% of total IV to be the dominant species and those with IV smaller than 0.1 to be locally rare species.

Active restoration

In December 2003, we established a species introduction experiment in an area adjacent to the plant survey. Saplings were grown in a greenhouse with ad libitum water and nutrients. On the time of introduction in the field, saplings varied from 30 to 50 cm depending on the species. Introduced plants were placed in holes of 0.15 m of diameter, with 0.2 m of depth, opened with 2 m tall heavy wooden stakes. These plants received no fertilization or irrigation after planting. During the subsequent two years, saplings were controlled