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PERSPECTIVE

A new focus for ecological restoration: management of degraded forest remnants in fragmented landscapes

Land use and land cover change is the major driver of biodiversity loss in terrestrial ecosystems worldwide, making the management and governance of land systems a key parameter in conserving and sustaining biodiversity. This issue gathers 16 contributions dealing with the relations between biodiversity and land systems from very diverse thematic and regional perspectives.

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Ricardo Augusto Gorne **Viani**[1] | Felipe Nery Arantes **Mello**[2] | Isaí Euán **Chi**[1]
Pedro Henrique Santin **Brancalion**[2]

A new focus for ecological restoration: management of degraded forest remnants in fragmented landscapes

Abstract

Ecosystem restoration is a global priority. Large-scale restoration programs have been recently launched with ambitious goals for forest restoration in fragmented tropical regions. Although cleared sites are being reforested in these regions, degraded forest remnants are often neglected regarding their restoration. We discuss why degraded forest remnants should be incorporated in the agenda of tropical forest restoration programs in currently fragmented regions, and the main challenges to make that an effective restoration strategy. Despite lower biodiversity and biomass, degraded forests are important for biodiversity conservation and human wellbeing in fragmented landscapes. Besides, the long-term sustainability of restoration sites embedded in fragmented landscapes depends on these forest fragments as biodiversity sources. Advances are necessary to consolidate the practice of restoring degraded forests. Lianas cutting, enrichment plantings and other restorations techniques need to be validated and policies to incentive restoration of those degraded forest need to be discussed with stakeholders involved in restoration.

Introduction

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER International Science & Policy Working Group 2004). Ecosystem restoration is now a global priority to reverse biodiversity loss, provide ecosystem services and strive to long-term sustainability of our human-dominated planet (Bullock *et al.* 2011; Aronson and Alexander 2013). Many large-scale restoration programs have been launched in the last years with ambitious goals (Pinto *et al.* 2014, Suding 2015). Until 2020, the Bonn Challenge aims to restore 150 million hectares around the globe while one of the Aichi Biodiversity Targets objectives is to recover at least 15% of degraded ecosystems globally.

While reducing emissions from deforestation and forest degradation (REDD) initiatives are more common in less fragmented landscapes, in older human-modified tropical landscapes, forest restoration programs are focused on recovering forests where they were cleared and substituted by other land uses. Meanwhile, restoration of several small and degraded forest remnants in those landscapes have been neglected (Brancalion *et al.* 2012). Thus, our objective is to discuss 1) why degraded forest remnants should be incorporated in the agenda of tropical forest restoration programs, and 2) the main challenges to make restoration of degraded forest remnants an effective strategy to reinforce biodiversity conservation and ecosystem services provisioning in fragmented regions of the tropics.

Why should we be concerned about restoring forest remnants in fragmented landscapes?

Forest fragmentation (forest areas are cut down in previously continuous forest habitats leaving small patches) have converted many tropical regions in landscapes with small and isolated forest fragments (Haddad *et al.* 2015). Following fragmentation, many tropical forests have faced degradation by selective logging, fire, grazing and/or other disturbances (Hosonuma *et al.* 2012). Both forest fragmentation and degradation affect species composition and ecosystem services provisioning in the remaining forest patches (Aguirre and Dirzo 2008; Pütz *et al.* 2011; Ferraz *et al.* 2014; Pütz *et al.* 2014). Remarkably, degraded tropical forest fragments experience an increase in abundance and biomass of some specific plant groups, such as bamboos (Lima *et al.* 2012) or, more commonly, climbers (Schnitzer and Bongers 2011). Climbers strongly compete with trees by water, nutrients and light, thus affecting trees physiological performance, growth, fecundity and survival (Schnitzer *et al.* 2005). As a result, degraded forest remnants have a strong reduction in tree species richness (Schnitzer and Carson 2010) and carbon stocks (Duran and Gianoli 2013). Consequently, degraded forests have constrains for provision of ecosystem

[1] Departamento de Biotecnologia e Produção Vegetal e Animal, Universidade Federal de São Carlos, Araras, SP, Brazil.
[2] Departamento de Ciências Florestais, ESALQ - Universidade de São Paulo, Piracicaba, SP, Brazil
Corresponding author: viani@cca.ufscar.br

services and landscape biodiversity conservation. Besides, depending on perturbation frequency, intensity and duration, these forest fragments may remain in a steady state of degradation, unless restoration actions are implemented.

Despite all the negative effects of fragmentation and degradation, remaining forest patches are important landscape biodiversity refugees (Arroyo-Rodríguez *et al.* 2009; Tabarelli 2010; Joly *et al.* 2014) and, if properly managed, good sources of propagules for surrounding areas (Viani and Rodrigues 2009). Even though they were historically degraded and exposed to edge effects, their biodiversity levels and resilience are much greater than that of areas where forest were completely cleared – currently, the focus of many forest restoration programs in fragmented landscapes. In such restoration sites, recovery of forest is frequently based on high-density native tree seedlings plantations (Rodrigues *et al.* 2011), which is expensive and sometimes uncertain in its success in recovering biodiversity (Maron *et al.* 2012). Thus, restoring degraded forest fragments could be in some cases more cost-effective for biodiversity conservation and ecosystem services provisioning at the landscape level than establishing forests in cleared sites where they no longer exist.

Even assuming that recovering forests in cleared areas is the focus of forest restoration programs, ecological restoration depends on the integration of the site under restoration into a larger ecological landscape, which interacts with it through abiotic and biotic flows and exchanges (SER International Science & Policy Working Group 2004). Natural regeneration is the main process for long-term sustainability of restored sites and is ultimately dependent on the presence of seeds and seed-disperses in surrounding forest fragments. If forest fragments are severely degraded and cannot provide shelter to seed-disperses nor have tree species seeds available in quantity and diversity, chances of forest restoration success in cleared sites are strongly reduced.

How to restore degraded forest fragments?

Techniques to restore a degraded forest fragment depend on its degradation level. In some cases, isolation from surrounding perturbations is

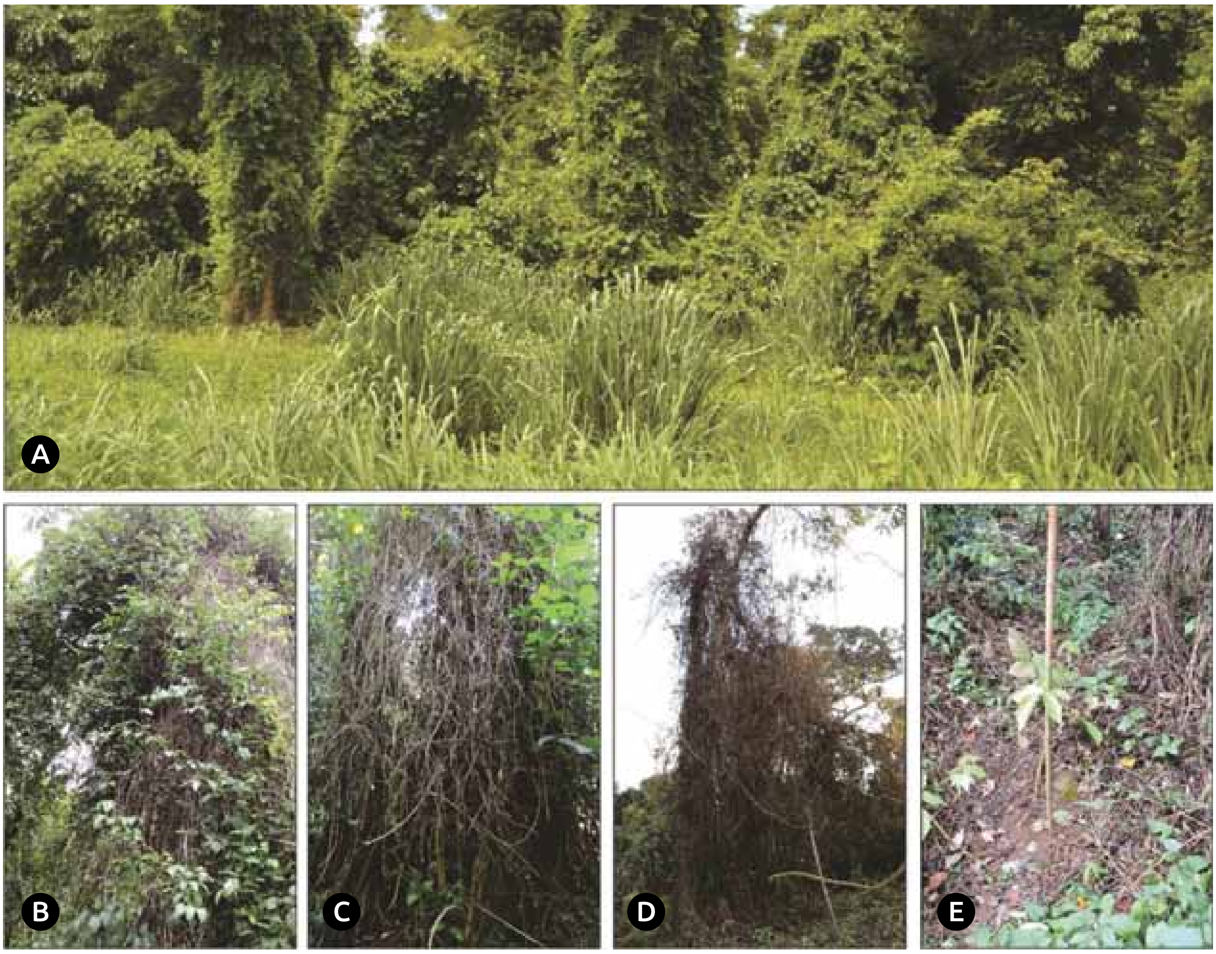

Figure 1: *The Vassununga Project in the Vassununga State Park, Santa Rita do Passa Quatro, SP, Southeastern Brazil: edge of a degraded forest fragment dominated by climbing plants (A); a whole tree covered by lianas (B); lianas dried some months after cutting (C-D); and a native tree seedling growing in the enrichment planting experiment (E).*

enough to forest self-recovering (Brancalion *et al.* 2012). However, in severely degraded landscapes, active restoration techniques are often needed.

The main technique to restore degraded fragments is the management of life forms that become hyperabundant, such as climbers (Rozza *et al.* 2007; Sfair *et al.* 2015). When climbers reach high densities and biomass, they cover whole trees and the forest canopy, reducing light availability for tree regeneration (Schnitzer *et al.* 2005). Operational field procedures consist in cutting the base of climbers, disconnecting them from the soil. Some months later, climbers dry up and fall down (Fig. 1). This process helps the reestablishment of tree canopy cover. Although it seems simple, climbers frequently resprout and grow fast again after cutting, which suggest that periodical cutting may be needed. In addition, despite being hyperabundant in degraded remnants, climbers are usually native species and an important life form for tropical ecosystems (Gentry and Dodson 1987). Thus, there is a debate on managing all or only the most abundant climbing plants (Sfair *et al.* 2015).

Even when periodically performed, climbers cutting may be not enough if the potential of natural regeneration in the forest fragment is severely impacted. In that occasions, restoration techniques to stimulate natural regeneration and forest succession, such as assisted natural regeneration, enrichment plantings and soil revolving to expose the soil tree seed bank to light, have been proposed to reestablish canopy cover (Rozza *et al.* 2007). In the assisted natural regeneration, control of invasive grasses and fertilization are performed around tree seedlings. In enrichment plantings, native tree seedlings are planted in the forest understory or in the gaps created by climbers cutting. Despite several studies have already been performed, results from experimental tests are not conclusive and not always successful, thus several challenges regarding their effectiveness, costs and operational feasibility remain.

The Vassununga project: a case study in the Atlantic Forest

To address the lack of large-scale projects aiming to validate the practice of restoring degraded tropical forest fragments, we established, in 2013, the Vassununga Project. It is a 10.6 ha long-term project established with the objective of investigating costs, operational feasibility and overall effectiveness of liana cutting, assisted natural regeneration and enrichment plantings as restoration techniques for degraded forest fragments. Vassununga project is located at Vassununga State Park (VSP, 21°42-43'S and 47°34'-38'W), a protected area in Southeastern Brazil that experienced a strong fire event in the 1970's and is in a steady state of degradation, with high abundance of climbers (Fig. 1). The study sites are within the Atlantic Forest biome. Atlantic Forest is a global biodiversity hotspot (Myers *et al.* 2000) with less than 16% of its original cover remaining in scattered distributed small and degraded forest remnants (Ribeiro *et al.* 2009). The project has the involvement of several stakeholders: 1) a private company that is compensating the impacts caused by a licensed construction; 2) environmental bodies that authorized this compensation with restoration techniques in VSP degraded forest remnants; 3) the public institution which takes care of the VSP; 4) a company implementing the restoration actions and; 5) researchers from Federal University of São Carlos and University of São Paulo, who are testing restoration techniques.

We established 54 plots of 45x44 m. Data collection has just been started and robust results will be generated in the following years. Early inventories estimated 13.7 climbers for each tree above 1 m height, a high relation compared to well-conserved forest (Gentry and Dodson 1987) that indicates that the study sites are severely degraded. In addition, we found that most of the climbers have small stem diameters (≤ 1.5cm), which is different from the ticker lianas typically found in less degraded forest landscapes (Laurance *et al.* 2001, Rice *et al.* 2004).

Next steps and final remarks

In fragmented landscapes, restoring forests in cleared areas is crucial to increase forest cover and provide some water-related ecosystem services when restoration sites are located in riparian buffers, for example. However, we clearly stated reasons for including restoration of degraded forest in the agenda of restoration programs in those landscapes: they are important for biodiversity conservation and ecosystem services provisioning at the landscape level. Besides, the long-term sustainability of other restoration areas strongly depend on these forest fragments as biodiversity sources. Nevertheless, advances are necessary to consolidate the practice of degraded forest restoration. Firstly, it is necessary to validate the main techniques to restore degraded forest remnants, with better investigation of their costs, operational procedures and overall efficiency. For that, large-scale restoration projects should be implemented in many tropical regions. Once these techniques are validated, the next step is to convince environmental bodies that in some conditions investing in managing degraded forest remnants may be more cost-effective than traditional recommendations of native tree plantings in cleared areas. Finally, it is necessary to discuss these strategies with other restoration stakeholders, aiming to develop policies to foster degraded forest restoration in fragmented landscapes. It is a long way to go, but ecological restoration is now a global priority and it is an opportune time to include new approaches in its science and practice.

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