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COMMENTARY

Restoration of tropical forests requires more than just planting trees, a lot more. . .

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Abstract

Forest restoration is an important tool for combating climate change and protecting biodiversity. In this issue of *Applied Vegetation Science*, Garcia et al. show that alone, planting trees is insufficient for fully restoring rain forest complexity. This study highlights the need for longer-term restoration plans, including enrichment plantings that speed the recovery of non-tree forest components once planted trees have established.

Commentary

The growing appreciation that forests are important for biodiversity conservation and mitigating climate change is leading to increasing numbers of private- and government-funded forest restoration plantings around the world. Despite this, most restoration plantings are still designed based on historical reforestation approaches or the opinions of local restoration practitioners. Scientific tests of best practices for obtaining specific forest restoration conservation goals are still rare. The gulf between restoration practice and science may be larger for rain forests than other terrestrial ecosystems, because active experimentation with rain forest systems is slow and logistically difficult.

Rain forest restoration involves the extreme challenge of not just bringing back the forest, but also restoring the highest levels of local biological diversity and structural complexity of any terrestrial ecosystem. Despite this, most rain forest restoration efforts take a very similar approach to what is generally done for temperate forests: the planting of rows of tree seedlings. Sometimes the restoration plots are maintained with understorey weed control, sometimes a second wave of trees are planted to replace those that have died but, in general, follow up 'treatments' are minimal, occur within 1–2 yrs of the original planting, and are focused on the planted trees themselves rather than aiding the restoration of unique non-tree elements of these forests (Lamb et al. 2005). This common 'framework' approach to rain forest restoration is based on the idea that if you bring back the canopy, the full complexity and diversity of the forest will eventually follow (Lamb et al. 2005).

In this issue of *Applied Vegetation Science*, Garcia et al. (2016) present compelling evidence that planting trees alone is insufficient to drive the rapid recovery of the whole rain forest plant community. They recommend that rain forest restoration needs to be done in progressive stages, to help distinct successional processes that may not all operate exactly as they do in naturally recovering systems. This may be especially important in areas where rain forests were cut long ago and thus lack a substantial seed bank or source of diverse propagules from non-planted species (Benítez-Malvido & Martínez-Ramos 2003; Jakovac et al. 2016).

Rain forest understories are well known to be distinct from rain forest canopies in their ecology and composition (Fig. 1). As rain forests around the world have become increasingly threatened, more and more studies have reported that deforestation and degradation impact the tree and understorey components of rain forests in distinct ways (Guariguata & Ostertag 2001; Chazdon 2003; Mayfield et al. 2013). The more recent literature on the recovery of rain forest understories suggests that the assembly mechanisms important for understorey recovery and succession are distinct from those impacting the canopy layers, a reality that drives different recovery trajectories of rain forest canopies and understories (Mayfield et al. 2013). Most reforestation approaches, including those employed in rain forest systems, are based on the premise that replanted forests should follow the same successional processes as naturally regenerating systems (Lugo 1997). This underlying assumption, however, focuses on tree succession – not whole system succession – and does not generally incorporate the growing understanding that understorey and canopy tree succession differ. Garcia et al.'s paper in this issue of *Applied Vegetation Science* is thus an important step in developing more effective and holistic approaches for rain forest restoration.

In their paper, Garcia et al. compare the recovery of the tree and non-tree components of four tropical rain forest restoration tree plantings in relation to reference remnant forests in the same landscape. They found that the tree portion of the replanted forests came to resemble the reference forest tree layers within 55 yrs of planting, but the understorey did not at all resemble reference rain forest understories within this time frame. Some readers may think that this finding reflects site-specific processes or peculiarities. Other studies from rain forests in other parts of the world, however, support Garcia et al.'s finding and suggest this is a more generalizable

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Fig. 1. Tropical rain forest understories, like this one in Costa Rica, support a high diversity of understorey specialist plants. There is mounting evidence, including that presented by Garcia et al. in this issue of *Applied Vegetation Science*, that these distinct rain forest layers require separate consideration in rain forest restoration projects. Specifically, Garcia et al.'s study suggests that enrichment plantings added several years after planted tree layers develop are likely needed to bring rain forest understorey recovery in line with recovery of rain forest tree layers.

phenomenon. For example, a global meta-analysis of naturally regenerating forests also found divergent recovery of rain forest understories and canopies. In particular, they found that understories were more functionally dissimilar from reference sites than forest canopies in several tropical systems (Mayfield et al. 2013). Sonter et al.'s 2011 study of a buffer planting in tropical Australia (that even did include understorey species in the initial planting) mirrored Garcia et al.'s findings in that the understorey in this planting was functionally quite distinct from reference understorey even as richness patterns recovered.

The time series analysis provided by Garcia et al. adds a key element to the literature on rain forest understorey recovery in that it shows that this problem is persistent and unlikely to resolve itself without aid (at least over reasonable time periods). Historical framework approaches to rain forest restoration are probably in part correct; without restoring a canopy it is next to impossible for understorey vegetation to recover. This is because many understorey plants require low light, cool conditions to survive. That said, bringing back a forest canopy is only the first step when it comes to restoring the rest of the forest. For instance, degraded (or developing) rain forest canopies often support very high abundances of vines and lianas, which shade out seedlings and restrict the development of the understorey (Benítez-Malvido & Martínez-Ramos 2003). The lack of available propagules from the surrounding landscape (Benítez-Malvido & Martínez-Ramos 2003; Jakovac et al. 2016) and the distinct processes involved in the assembly of the understorey further create a distinct and often delayed recovery trajectory of rain forest understories (Mayfield et al. 2013). Clearly, restoring rain forest canopy layers is a must for rain forest restoration, but as Garcia et al. point out, restoration of rain forest understorey requires a longer-term investment and post-canopy development interventions.

Although logical and ecologically sensible, the recommendation to use enrichment plantings years after trees are planted in rain forest restoration projects is currently problematic under common restoration funding models. Even the best-intentioned government restoration programmes rarely consider the on-going costs associated with ensuring quality restoration outcomes. It is, in truth, much easier to find funding to plant trees than to return to control weeds or do enrichment plantings. As evidence mounts, however, that the recovery of rain forest diversity and function cannot be easily achieved by once-off tree plantings, I hope that studies like Garcia et al.'s will aid in the revision of restoration funding models to account for the complexity involved in rain forest restoration.

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