

# Applied Nucleation as a Forest Restoration Strategy: Lessons Learned

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## Overview

Given recent global targets to restore millions of hectares of forest, there is a critical need to test restoration strategies that are cost effective at large scales. One promising approach is applied nucleation. These tree nuclei or 'islands' serve to increase animal seed dispersal and shade out pasture grasses, common obstacles to tropical forest recovery, and thereby enhance woody seedling recruitment. In the applied nucleation model, tree islands expand and coalesce over time and facilitate the establishment of later-successional species by improving local microclimatic conditions. Fewer trees are planted using this method, thereby reducing planting and maintenance costs, and the approach has the potential to create more heterogeneous habitat conditions. Despite the promise of applied nucleation, there have been few studies conducted to date. We summarize results of a well-replicated, 14-year old project comparing natural recovery, plantation-style tree planting, and applied nucleation across a 100 km<sup>2</sup> area in southern Costa Rica.

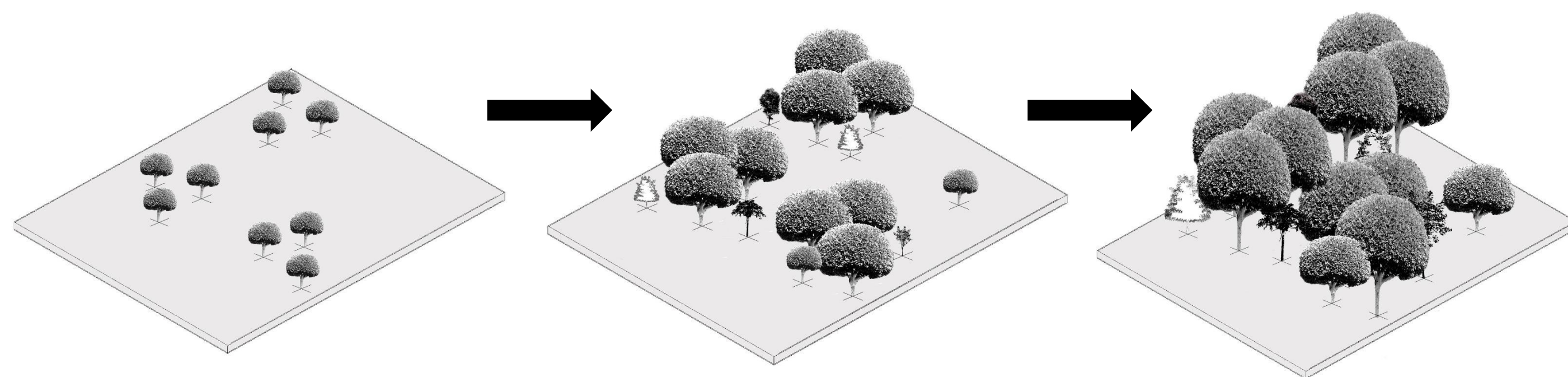
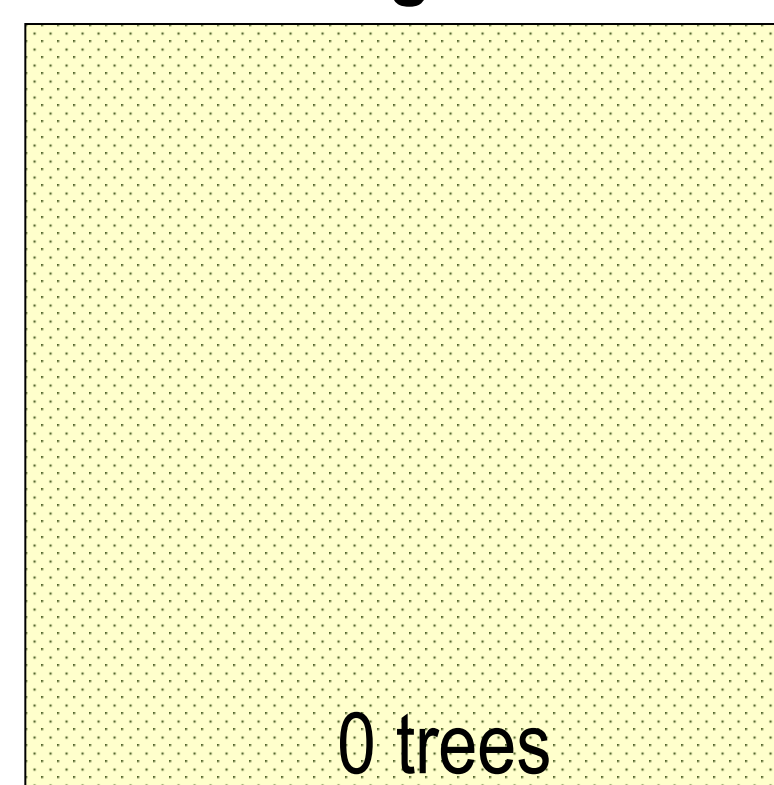


Fig. 1. Applied nucleation model of forest restoration. Corbin & Holl 2013. For. Ecol. Man. 26:37-46.

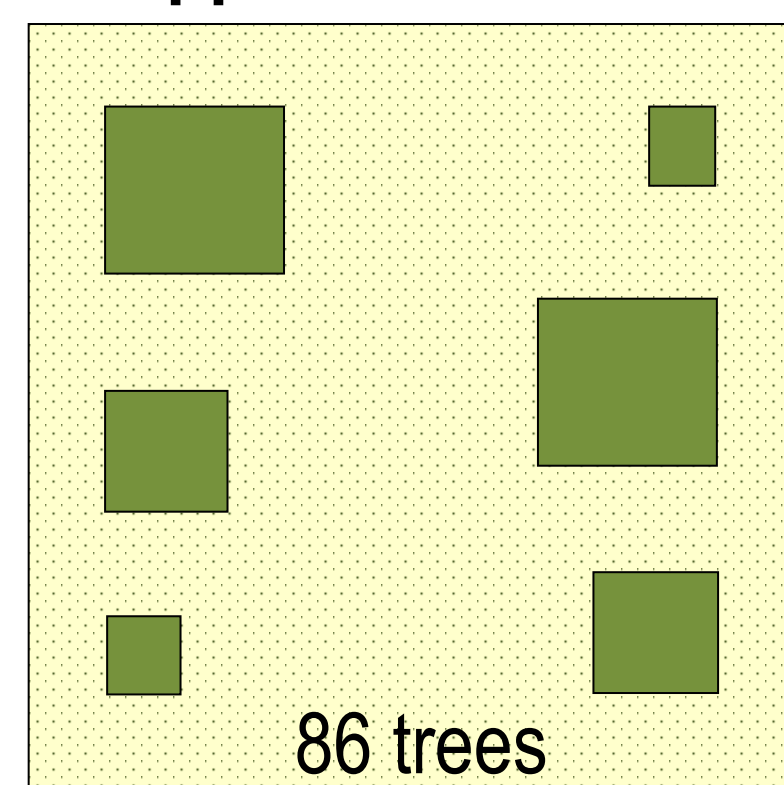
## Experimental design

- Established 13 experimental sites at 1000-1400 m elevation between 2004 and 2006.
- At each site there are three 50×50 m treatments: Natural regeneration – no planting; Applied nucleation – planting with six tree islands of three sizes (4×4, 8×8, and 12×12 m); and Plantation – planting the entire plot with trees.
- Interplanted two native tree species (*Terminalia amazonia* and *Vochysia guatemalensis*, and two naturalized softwoods (*Erythrina poeppigiana* and *Inga edulis*) that are used widely in intercropping systems in Central America.
- Cleared grasses around tree seedlings for 2.5 years following plot establishment.
- Have monitored recovery of birds, bats, seed rain, woody recruitment, leaf litterfall, soil arthropods, mycorrhizae, soil nutrients, epiphytes, and more.

### Natural regeneration



### Applied nucleation



### Plantation



## Lessons Learned

**1. Applied nucleation and plantation restoration strategies are similarly effective in enhancing the recovery of most ecosystem functions and floral and faunal groups, as compared to natural regeneration.** Nearly all variables measured have shown similar values in applied nucleation and plantation plots, although many are still substantially lower than references forest plots a decade after restoration.

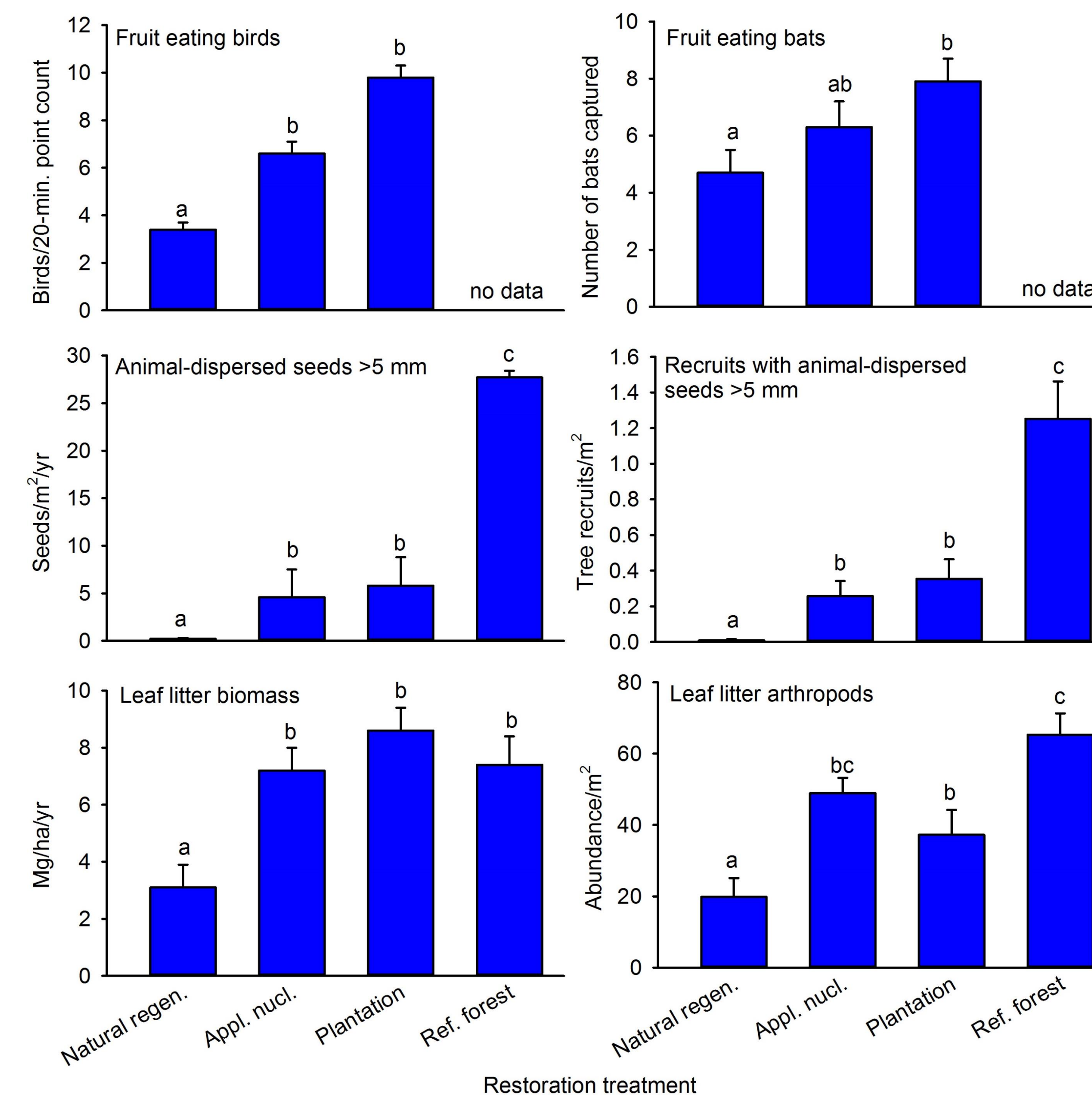


Fig. 2. Faunal and floral comparisons across natural regeneration, applied nucleation, plantation, and reference forest plots. Values are means  $\pm$  1 SE.

**2. There is a minimum tree island size necessary to enhance seed dispersal and seedling recruitment.** Not only are small tree islands (4×4 m, 5 trees) not as effective in facilitating recovery, seedlings in these islands are more likely to be cut accidentally when clearing grass during the first couple of years after plot establishment.

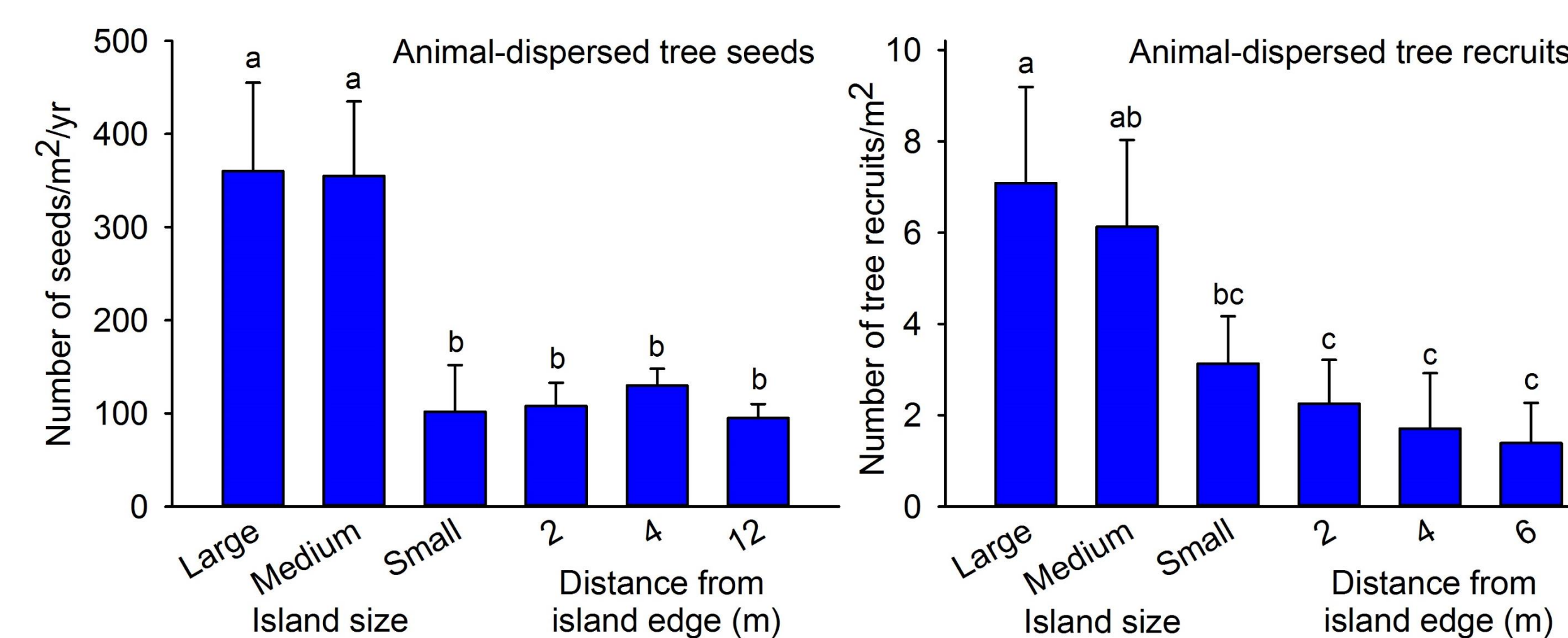


Fig. 3. Animal-dispersed tree seeds and recruits in different tree island sizes and at varying distances from the island edge in unplanted areas. Values are means  $\pm$  1 SE.



1-yr old plantation



9-yr old plantation

**3. Tree island cover has expanded rapidly from <25% cover initially to >50% cover after a decade.** Canopy cover has increased rapidly in our study due to both growth of planted trees and woody recruitment at tree island edges demonstrating the ability of island to spread and coalesce, which is critical to the long-term success of the applied nucleation approach.

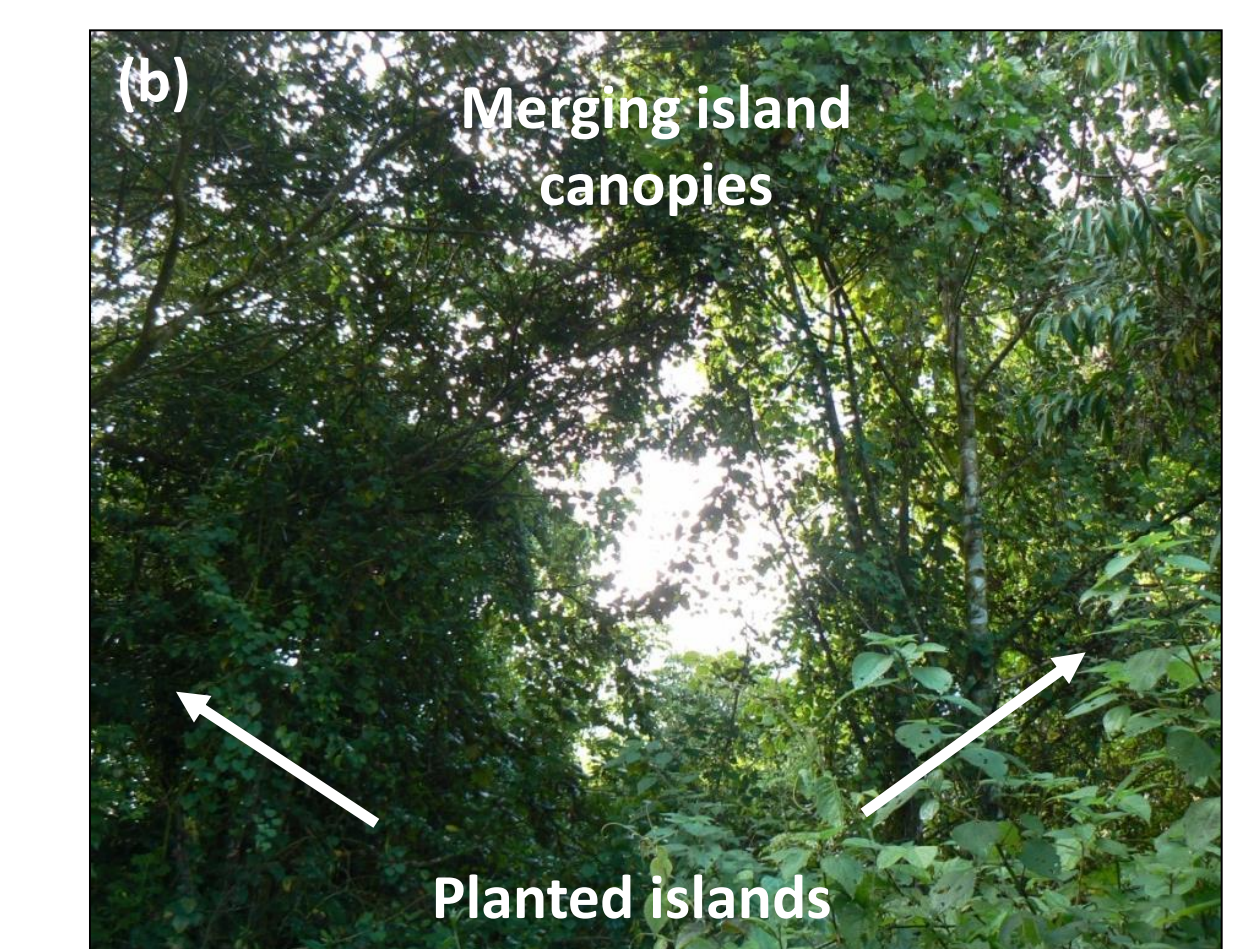
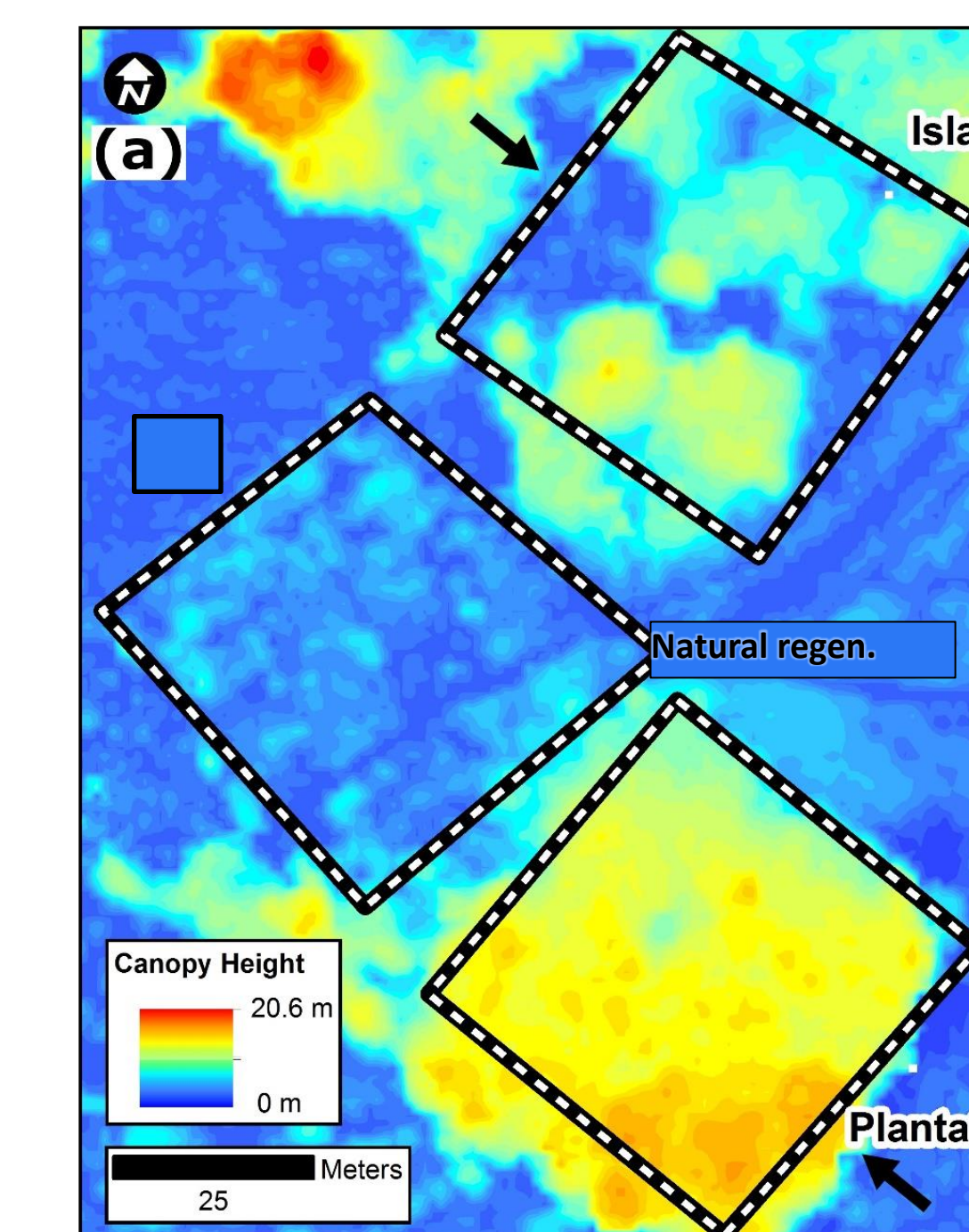


Fig. 4. (a) Canopy height measured with an unmanned aerial vehicle 10 years after planting; (b) two island canopies merging at the center.

**4. There are some logistical and social challenges to applied nucleation.**

- The applied nucleation irregular planting design resulted in more accidental damage to planted seedlings when clearing grasses at the outset of the study.
- Similar to areas undergoing natural regeneration, applied nucleation results in more heterogeneous cover which is considered "messy" by some land owners who would prefer to have desirable tree species planted throughout their land to maximize land usage.

## Conclusions

Our results demonstrate that the applied nucleation restoration approach can be similarly effective in facilitating forest recovery as more intensive planting approaches. Moreover, the planting and seedling maintenance costs are substantially lower in the first few years, since seedling planting and maintenance costs are proportional to the area planted. We advocate further large-scale experiments to evaluate the ecological and socioeconomic conditions in which applied nucleation could be a more appropriate restoration approach.

### For more information

Project publications, both for general and scientific audiences, that provide more detail on the results presented can be accessed at: [www.holl-lab.com/tropical-forests.html](http://www.holl-lab.com/tropical-forests.html)

