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RESEARCH ARTICLE

Planting Seedlings in Tree Islands Versus Plantations as a Large-Scale Tropical Forest Restoration Strategy

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Abstract

Planting tree seedlings in small patches (islands) has been proposed as a method to facilitate forest recovery that is less expensive than planting large areas and better simulates the nucleation process of recovery. We planted seedlings of four tree species at 12 formerly agricultural sites in southern Costa Rica in two designs: plantation (entire 50 × 50 m area planted) and island (six patches of three sizes). We monitored seedling survival, height, and canopy area over 3 years. To elucidate mechanisms influencing survival and growth, we measured soil and foliar nutrients, soil compaction, and photosynthesis. Survival of all species was similar in the two planting designs. Seedling height and canopy area were greater in plantations than islands at most sites, and more seedlings in islands decreased in height due to damage incurred during plot maintenance. Survival, height, and canopy area were both site- and species-specific with the two N-fixing species (*Inga edulis* and *Erythrina poeppigiana*) greater than the other species (*Terminalia amazonia* and *Vochysia guatemalensis*). Foliar N was higher in *Terminalia* and *Vochysia* in sites where *Inga* growth was greater. Soil nutrients, however, explained a small amount of the large differences in growth across sites. Leaf mass per area was higher in islands, and P use efficiency was higher in plantations. Our results show advantages (good seedling survival, cheaper) and disadvantages (more seedling damage, slightly lower growth) to the island planting design. Our study highlights the importance of replicating restoration strategies at several sites to make widespread management recommendations.

Key words: Costa Rica, nucleation, premontane forest, reforestation, seedling growth.

Introduction

Planting tree seedlings is a common restoration strategy and is often successful in accelerating tropical forest recovery (e.g. Parrotta & Knowles 2001; Cusack & Montagnini 2004; Lamb et al. 2005). If seedlings provide canopy cover they can overcome many barriers to forest regeneration in degraded tropical sites (e.g. increasing seed rain, ameliorating microclimatic extremes, shading out pasture grasses), and thus facilitate the natural establishment of a diversity of forest species (reviewed in Holl 2002b). This strategy can be expensive, however, especially when large areas are restored (Parrotta & Engel 2001; Rodrigues et al. 2009).

A few studies have tested planting trees in patches or "islands" (Robinson & Handel 2000; Zahawi & Augspurger 2006; Rey Benayas et al. 2008) rather than as plantations. This practice mimics the natural nucleation process (Yarranton & Morrison 1974) in which primary colonists establish in patches and spread outward clonally and/or by facilitating the colonization of later-successional species. This process has been widely documented for remnant trees and shrubs in tropical old fields (e.g. Guevara et al. 1992; Vieira et al. 1994; Holl 2002a; Schlawin & Zahawi 2008). If seedlings planted in islands show similar survival and growth to plantations and facilitate the establishment of other plant species (Zahawi & Augspurger 2006; Cole et al. in press), then island plantings may be a more cost-effective restoration strategy. However, the two approaches have never been compared rigorously.

Most past tropical forest restoration studies have been restricted to a single or a few sites (e.g. Cusack & Montagnini 2004; Carpenter et al. 2004a; Siddique et al. 2008). The few studies conducted at multiple sites (Piotto et al. 2003; Calvo-Alvarado et al. 2007; Wishnie et al. 2007) or blocks within sites (Carpenter et al. 2004a) show that seedling growth rates can be highly variable, even on a small scale. Accordingly, it is not often possible to extrapolate results to a regional level, and the high variability underscores the importance of testing restoration strategies at multiple sites to clarify the mechanism(s) underlying differences in seedling growth.

Tropical seedling growth in abandoned agricultural lands is limited by numerous factors including soil physical and chemical conditions, competition with existing vegetation, and microclimatic conditions (reviewed in Holl 2002b). Designing

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