

LONG LEGACIES OF FUTURE CROP TREE LIBERATION IN GUYANA

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In order to sustain timber yields from selectively logged tropical forests, a commonly advocated silvicultural treatment is to release future crop trees (FCTs) from competition by cutting lianas (i.e., climbers or woody vines) and girdling over-topping trees (i.e., liberation thinning). In a lowland forest in Central Guyana, we tracked development of 20–40 cm DBH FCTs in permanent sample plots for 21-years after three treatments each replicated three times; firstly through low-intensity reduced-impact logging (RIL; 8 trees/ha) followed by FCT release, secondly by low-intensity RIL only, and thirdly with no logging. The benefits of FCT liberation to three common commercial timber species (*Chlorocardium rodiei*, *Carapa guianensis*, and *Castostemma fragrans*) were still evident 21-years after treatment (23-years after logging). Compared to conspecific FCTs of the same size at the time of treatment in the logged-but-untreated and in the unlogged control areas, the crowns of liberated FCTs remained more exposed to light, grew faster, and fewer suffered liana infestations.

Keywords: Lianas, liberation thinning, natural forest management, silviculture, sustainable forest management, tropical forestry

INTRODUCTION

While market demands for tropical timber are undiminished, it is increasingly clear that even faithful application of reduced-impact logging (RIL) practices does not guarantee sustainability of timber yields with selective logging at legally permitted harvest intensities and frequencies (Ruslandi et al. 2017, Peħa-Claros et al. 2008, Roopsind et al. 2017, Sist et al. 2021, Bedrij et al. 2022). Sustained timber yields (STY) are possible if cutting cycles are extended, harvest intensities are reduced, or silvicultural treatments are applied to increase the stocking and growth of trees that produce merchantable timber (Putz et al. 2021). Alternatively, volumetric yields can be sustained if, with each harvest, smaller and lower quality logs of newly marketable species are included in the calculations (Castro et al. 2021). While sequential depletion of commercial species and reductions in standing volumes of timber seems contrary to the philosophy of

sustainability, such compromises are practical and preferable to the alternative of forest conversion.

Two often recommended silvicultural treatment for stimulating timber volume increments in uneven-aged forests are to liberate future crop trees (FCTs; well-formed trees of commercial species that are smaller than the minimum harvest diameter) from lianas (Putz et al. 2023) and from crowding by non-commercial trees, the latter referred to as liberation thinning (de Graaf et al. 1999, Pariona et al. 2003, Wadsworth & Zweede 2006, Peħa-Claros et al. 2008). While there is substantial agreement about the growth benefits of cutting lianas on FCTs (Estrada et al. 2022, Finlayson et al. 2022), there is less agreement about the costs and benefits of liberation thinning especially when carbon stocks are monetised (van der Hout 1999, Gräfe et al. 2020). Debates

about the effectiveness of these silvicultural treatments suffer from lack of data on their long-term effects. Due to this deficiency in data, it is generally assumed that the benefits of FCT liberation only persist for a decade (de Graaf et al. 1999). We present the results of the long-term effects of liberation on FCT crown exposure, liana infestations, and growth rates in a lowland tropical forest in central Guyana.

The need for post-harvest silvicultural treatments to increase FCT growth is acute in Guyana Shield forests where the principal commercial species have dense wood and grow slowly on extremely nutrient-poor soils (Roopsind et al. 2018). Logging intensities in these forests are typically low (5–10 m³ ha⁻¹) and residual FCTs are expected to constitute the next harvest. We note, however, that without silvicultural treatments, evidence that timber yields are not sustainable prompted the United Kingdom's Environmental Agency in 2015 to ban imports from Guyana of its principal timber, *Chlorocardium rodiei* (greenheart).

The objectives of this research were to assess the long-term effects of liberation on FCT crown positions, liana infestations, and stem diameter growth rates. We predicted that liberation would result in higher FCT growth rates in response to reduced competition by increasing crown exposure to sunlight and removal of lianas.

MATERIALS AND METHODS

Study area

The research was conducted in permanent sample plots established in the early 1990s by Tropenbos International as part of long-term studies in Pibiri, Central Guyana (5° 02' N, 58° 37' W) (Figure 1). The study site is in a timber concession 40 km south of Mabura Hill and approximately 250 km south of the capital, Georgetown, at elevations of 50–100 m above sea level. The mean annual precipitation is 2400–3000 mm, mean annual temperature is 25° C, and the land gently undulates with slopes mostly <10%. The evergreen forest grows on extremely nutrient-poor but well-drained sandy clay soils (van der Hout 1999).

The forest in the study site is dominated by a diversity of slow-growing, large-seeded tree species with high-density wood with noteworthy

clusters of *C. rodiei* (greenheart), a popular commercial timber species. Other common canopy tree species found include *Lecythis confertiflora* (wirimiri), *Swartzia leiocalycina* (wamara), and *Castostemma fragrans* (sand baromalli), with local concentrations of *Mora gongrijpii* (morabukea) uphill of gullies and *Carapa* spp. (crabwood) and *Pentaclethra macroloba* (trysil) in wet areas. Further details about the area's climate, soils, geology, and forest composition can be found in ter Steege et al. (1996) and van der Hout (1999).

Silvicultural treatments

The study employed a randomised block design that included nine permanent sample plots of 140 m × 140 m (1.96 ha), with experimental treatments also applied to 50 m-wide buffer zones around each plot. We focused on the three unlogged control plots, three low intensity reduced-impact logging (RIL) (8 trees ha⁻¹) plots, and three plots subjected to the same low intensity RIL harvest followed, two years later, by a post-harvest FCT liberation treatment. All trees >20 cm diameter at breast height (DBH; diameter at 1.3 m or above buttresses) were mapped, measured, and identified to species (van der Hout 1999).

The first census of the plots was conducted in 1993 (pre-logging) with RIL executed in 1994. In 1996, future crop trees (FCTs), defined as 20–40 cm DBH trees of commercial species and good form, were liberated from competition by cutting all attached lianas and poison-girdling overtopping trees of non-commercial species or bad form. The tree girdling treatment involved a complete chainsaw girdle well into the sapwood followed by application of glyphosate. The plots were fully re-measured in 1997, 2000, and 2013, with re-measurements of FCTs of the three focal species in 2017 and 2019. For each census, DBH, crown position and the presence or absence of lianas were recorded.

Study species and data collection

Carapa guianensis, *Castostemma fragrans*, and *Chlorocardium rodiei* (hereafter referred to by their generic names) were selected for this study because they were well represented in all

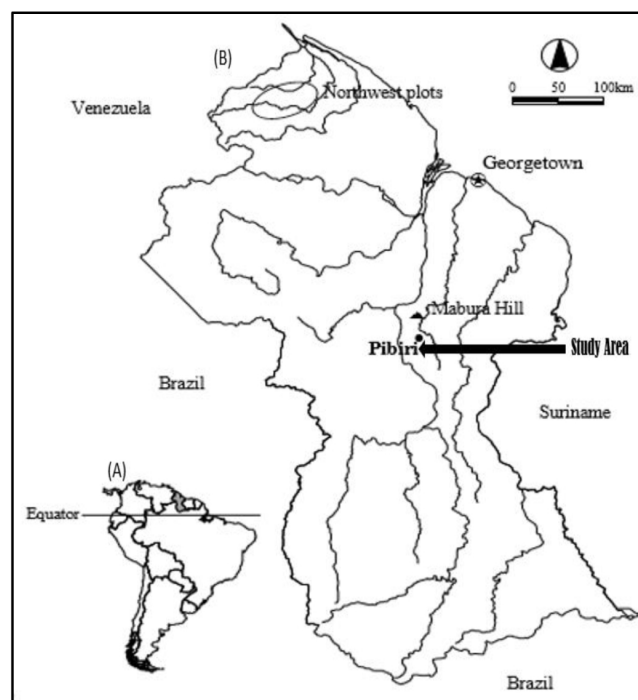


Figure 1 Location of the Pibiri Research Site and nearby rivers within (A) South America and (B) Guyana

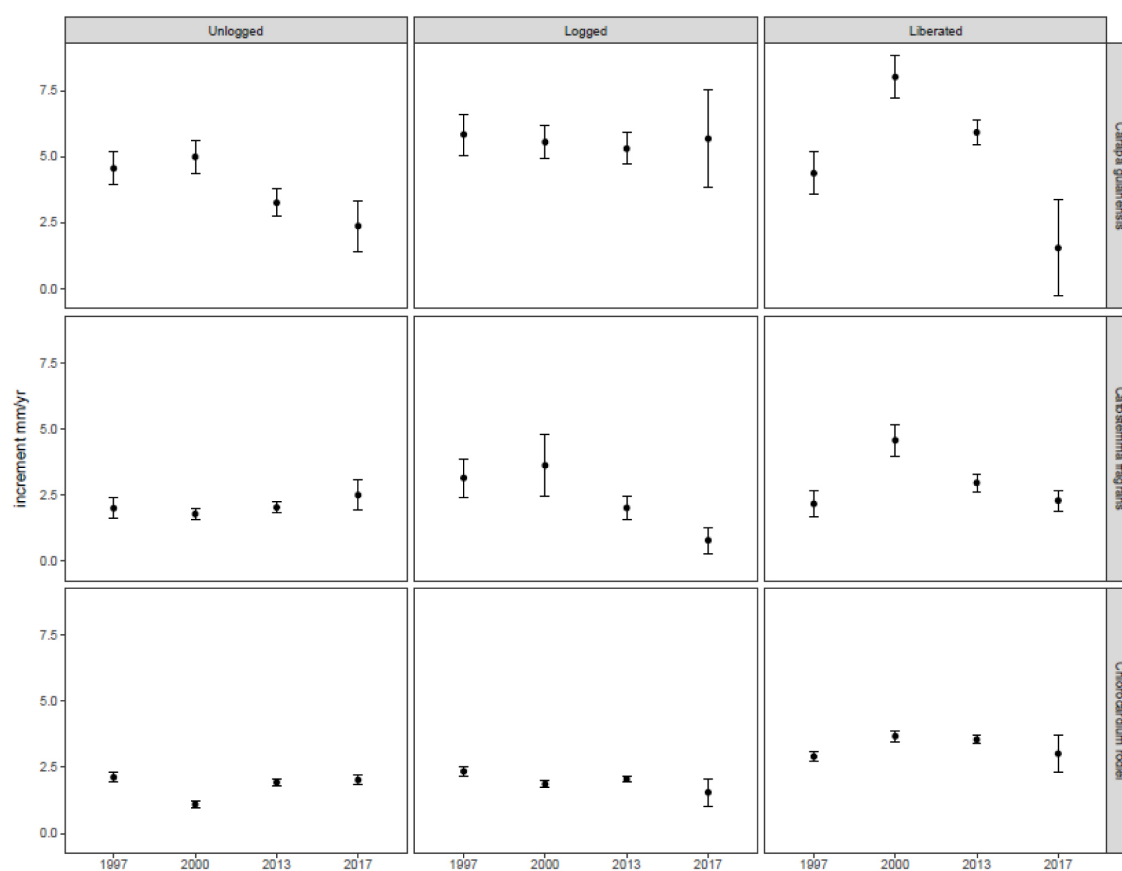


Figure 2 Future crop tree (FCT) growth rates (mean $\pm$ 1 standard deviation) of three commercial timber species in unlogged control plots, in plots logged in 1994 with no further treatment (logged), or logged in 1994 with FCTs liberated from lianas and neighboring trees with over-topping crowns in 1996

the plots and all produce valuable commercial timber with high densities (0.67, 0.61, and 0.94 g cm⁻³, respectively; Zanne et al. 2009). From the total list of eligible trees, FCTs and potential FCTs were randomly selected for sampling. DBHs were measured, each tree was assigned to a Dawkins crown position class (Alder & Synnott 1992), and crown infestations by lianas were recorded as present or absent.

RESULTS

The effects of logging and logging-plus-liberation on FCT growth rates varied among species and over time, but liberated trees generally grew the fastest (Figure 2). *Carapa* showed a marked growth benefit of logging alone followed by logging plus liberation, but the effects of the

latter treatment varied substantially over time. In contrast, growth rates of *Castostemma* FCTs showed little response to logging, and only a brief period of accelerated growth in the logged and liberated plots. Similarly, *Chlorocardium* FCTs did not respond to logging by growing more rapidly but showed modest but consistent increases in growth rates in response to the combination of logging and liberation.

The benefits to FCTs of liana cutting persisted for at least 21 years after treatment. Proportions of liana-infested trees doubled after logging relative to unlogged forest but was halved when logging was followed by the liana liberation treatment (Table 1). The proportion of liana-free FCTs was increased by the treatment, as expected, and remained high 17 and 21 years later (Figure 3).

Table 1 Liana infestations of future crop trees (FCTs) 21-years after a liberation thinning treatment in which all infesting lianas and over-topping neighbor trees were cut and poison girdled, respectively

Treatment	Liana infested (%)	Not infested
Unlogged	43 (36.1%)	76
8 trees logged	53 (77.9%)	15
8 trees logged + FCTs liberated	10 (17.2%)	48

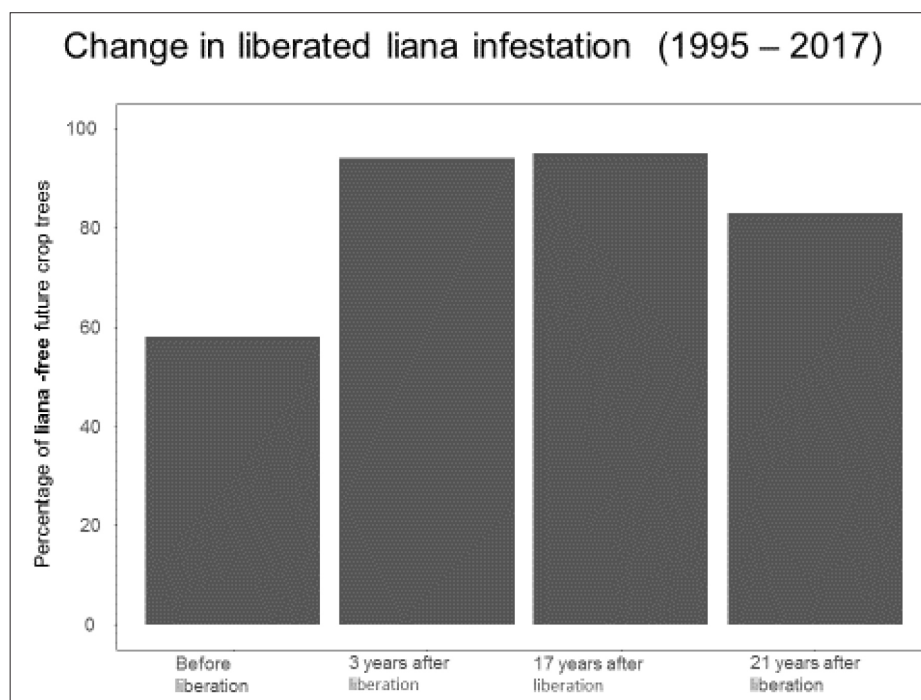


Figure 3 Temporal changes in the proportions of liana-free FCTs from before to 21-years after the logging plus liberation thinning treatment that included liana cutting

Table 2 Crown positions of FCTs 21-years after a liberation treatment that included poison-girdling of overtopping trees of non-commercial species and those with bad form

Treatment	Shaded	Exposed (%)
Unlogged	18	101 (84.9%)
8 trees logged	14	55 (79.7%)
8 trees logged + liberation	12	43 (78.2%)

The effects of FCT liberation from competition from neighboring trees on crown exposure was less clear than the effects of liana cutting. Twenty-three years after logging and 21-years after the overtopping neighbors were poison-girdled in the treated plots, there was no apparent effect of logging or logging-plus-liberation on the proportion of FCTs with exposed crowns (Table 2).

DISCUSSION

Long-term benefits of FCT liberation from lianas

The impacts of liana cutting on the proportions of liana-infested FCTs was still evident 21-years after the treatment. Among the infested trees were those that were newly colonized and trees with lianas that were apparently missed when the treatment was applied, as observed in other studies (Mills et al. 2019). One explanation for the long-term benefits of liana cutting is that, after the cut lianas fell, liana access to the canopy was undoubtedly limited by the loss of trellises provided by dead hanging liana stems. The likelihood of new colonization from adjacent canopy trees was also reduced by the poison-girdling of overtopping tree treatment (i.e., liberation thinning) because it increased the distances canopy lianas need to span between neighbors and FCTs. Due to mechanical restrictions on leader shoot length, few lianas can cross inter-crown gaps of more than 2-3 m (Putz 1984, Hattermann et al. 2022). Many of the lianas we presume were missed by workers were thick-stemmed and grew onto FCT crowns from neighbors. Workers assigned the task of liana cutting naturally focus on those that dangle down near FCT trunks and not those that colonize their crowns from the crowns of neighbors (Mills et al. 2019).

Effect of liberation on FCT crown exposure and growth rates

In contrast to the substantial and prolonged growth benefits of liana cutting, the benefits from liberation of FCTs from overtopping neighbors were less clear. This finding contrasts with previous reports from other forests (Wadsworth & Zweede 2006, Peña-Claros et al. 2008, Villegas et al. 2009, David et al. 2019). One observation of likely relevance is that our poison girdling treatment did not immediately kill the treated trees; even 20 years after treatment, some were still alive. Although we lack data on the time course of post-treatment tree deaths, among the long-term survivors were several large individuals of *Mora gongrijpii*, a species with characteristically tall plank buttresses that make chainsaw girdling very challenging. Furthermore, some of the surviving poison-girdled trees of that species produced adventitious roots from above the girdle, which suggests insensitivity to glyphosphate herbicide.

CONCLUSIONS AND RECOMMENDATIONS

It is encouraging that the benefits of liberation of FCTs from lianas were still effective 21-years. In contrast, liberating FCTs by killing neighboring trees with overlapping crowns does not seem worth the financial and environmental costs including the carbon emissions, as argued by Gräfe et al. (2020). Another reason to avoid poison-girdling trees is that what constitutes a merchantable bole changes over time. For example, when the Pibiri plots were treated in 1996, *Swartzia leiocalycina* was one of the species killed because there was no market for its timber; wood from that species now fetches extremely high prices. Similarly, if demand grows for rot-resistant timber such as that of *Chlorocardium*,

even hollow and poorly formed trees will have commercial value. Another concern is that poison girdling of extremely large trees, even those with hollow stems, is an environmentally undesirable practice given their importance to wildlife, as seed sources, and as carbon stocks. Finally, we urge caution when entering stands with poison-girdled trees that are still standing due to the risk of being injured by falling branches.

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