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Current Brazilian forest management guidelines are unsustainable for *Swietenia, Cedrela, Amburana,* and *Copaifera*: A response to da Cunha and colleagues

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A response to the following paper:
da Cunha, T. A., Finger, C. A. G., Hasenauer, H. (2016) Tree basal area increment models for *Cedrela*, *Amburana*, *Copaifera* and *Swietenia* growing in the Amazon rain forests. *Forest Ecology and Management* 365: 174-183.

Keywords: Brazil; sustainable forest management; harvest regulations; big-leaf mahogany; Spanish cedar; copaiba

Current Brazilian forest management guidelines are unsustainable for *Swietenia, Cedrela, Amburana,* and *Copaifera*: A response to da Cunha and colleagues

In their recent *Forest Ecology and Management* paper, da Cunha et al. (2016) reconstruct annual basal area increments from tree cores for *Swietenia macrophylla* (big-leaf mahogany), *Cedrela odorata* (Spanish cedar), *Amburana cearensis* (amburana), and *Copaifera paupera* (copaiba) in the Brazilian Amazon and relate species-specific growth rates to four tree size indices, two competition indices, and liana load (the study species are hereafter referred to by their generic names). The reconstruction of growth histories and statistical tests of relationships between growth and crown form, light environment, and competition represent important contributions to the growing body of research on Amazonian tree life history and management. Unfortunately, the authors attempt to use this valuable but limited information to draw broad conclusions about the sustainability of current Brazilian management regulations. Ultimately, they conclude that their study *"confirms that the current forest management guidelines and regulation [sic] applied in the Amazon rain forest are conservative but correct estimates and ensure sustainable harvesting"* (pg. 182). We argue that da Cunha et al. provide no evidence to support this claim and actually report results that coincide with more comprehensive studies demonstrating that current Brazilian harvest regulations are unsustainable without longer cutting cycles, higher retention rates, and extensive silviculture.

It is reckless to make sweeping statements regarding the sustainability of harvest regulations, especially for threatened species like *Swietenia* and *Cedrela* (listed on CITES Appendices II and III, respectively), without directly examining the recovery of tree densities and harvest volumes under all of the relevant regulatory parameters. Nevertheless, da Cunha et al. conclude that current Brazilian harvest regulations – which employ a 50 cm minimum diameter cutting limit (MDCL), 25-35 year cutting cycles, and an 80% maximum cutting intensity – are sustainable based only on their models of the time required for trees to pass from 30 cm diameter to commercial size (**Table 1**). However, the meaning of this arbitrary passage time is unclear. If it is meant to show that trees reach commercial size within a commercial rotation, then the time from seed to commercial size is the relevant and necessary statistic. However, even this statistic is insufficient for evaluating sustainability without consideration of size structure and mortality rates, both of which are completely ignored by da Cunha et al.. Furthermore, da Cunha et al. fail to consider cutting intensity, which is necessary in any evaluation of harvest sustainability.

The peer-reviewed studies that do directly and comprehensively evaluate current harvest regulations demonstrate that they are unsustainable for the four study species. For example, Brienen and Zuidema (2006b) use a simple population growth and yield model to examine the sustainability of current Bolivian forest regulations for *Cedrela* and *Amburana* over one cutting cycle (20 years) with a 50 cm MDCL and 80% cutting intensity. They found that it takes ~72 years and >84 years to recuperate initial harvest volumes of *Cedrela* and *Amburana,* respectively, demonstrating that Brazilian harvest regulations, even with their longer cutting cycles, would be unsustainable for these species. Grogan et al. (2014) use an even more detailed individual-based population model that incorporates growth, mortality, fruit production, seed germination, and canopy disturbance rates to evaluate the sustainability of current Brazilian harvest regulations for *Swietenia* and show that current regulations lead to commercial depletion after 2-3 cutting cycles. Although harvest regulations for *Copaifera* have yet to be evaluated, they are unlikely to be sustainable given that *Copaifera* exhibits the slowest growth rates of the four study species.

These studies, unlike da Cunha et al., explicitly evaluate both population density and harvest volume outcomes under current regulations while accounting for mortality and size structure and simply cannot be refuted by conclusions based on a meaningless passage time. In fact, the results of da Cunha et al. actually validate conclusions that current Brazilian harvest standards are unsustainable. The 30-50 cm diameter passage times documented by da Cunha et al. are nearly identical to those documented in studies showing that current cutting cycles are too short for these slow-growing species (**Table 1**; Brienen and Zuidema 2006b; Free et al. 2014; Grogan et al. 2014). da Cunha et al. also demonstrate that extensive silviculture is required to promote the fast growth rates necessary for sustainable and profitable logging to be achievable. They show significant decreases in 30-50 cm diameter growth rates from ideal to moderate growth conditions for all four species and these decreases likely compound over the more relevant 0-50 cm diameter passage time. The necessity of extensive and expensive silviculture, often unattractive to loggers through the lens of financial discount rates, undermines da Cunha et al.'s assertion that current forest management regulations are *"conservative"* (pg. 182).

In their opening sentence, the authors assert that *"little is known about sustainable forest management and tree growth in the Amazon forest"* (pg. 174). In reality, tropical forest ecologists and managers have learned a lot about the factors contributing to the success and failure of sustainable forest management in the last few decades and knowledge of tree growth dynamics has been central in these developments. For example, we know that: (1) harvest parameters such as the minimum diameter cutting limit, cutting cycle length, and cutting intensity must be coupled to species-specific biological realities (Schöngart 2008); (2) sustainable management will require extensive silvicultural intervention including enrichment planting, crown liberation, liana cutting, and gap creation (Wadsworth and Zweede 2006; Peña-Claros et al. 2008; Schwartz et al. 2016); (3) reduced-impact logging can reduce the ecological impacts of logging (Putz et al. 2008); and (4) community-based forest management, forest certification programs, and REDD+ subsidy programs can incentivize sustainable behavior (Gray et al. 2001; Putz et al. 2012). Thus, the slow progress towards sustainable management is due, not to a lack of scientific knowledge, but to a lack of political will and incentives that counterbalance the opportunity costs and investments essential to truly sustainable management systems.

Although da Cunha et al. draw erroneous conclusions regarding the sustainability of Brazilian forest management, they do provide some useful results. First, they confirm that silvicultural interventions such as liana cutting and crown liberation are effective and necessary tools for sustainable forest management. Second, although the growth and age-size dynamics of *Swietenia* and their management implications have been well studied (e.g., Gullison et al. 1996; Grogan et al. 2003, 2005, 2008; Grogan & Landis 2009; Grogan & Schulze 2012; Free et al. 2014), *Cedrela* and *Amburana*'s dynamics have been less well studied (e.g., Brienen & Zuidema 2006ab; Zuidema et al. 2009), and the da Cunha et al. *Copaifera* results are entirely novel and highly valuable to scientists and managers. Finally, this paper contributes to the growing literature demonstrating that tropical trees can be aged and that describing species-specific growth rates and age-size relationships are essential to the future of sustainable forest management in the tropics (Worbes 2002).

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Tables & Figures

Table 1. 30-50 cm and 0-50 cm diameter passage times reported by da Cunha et al. (2016) compared to other studies. The 30-50 cm diameter passage time (reported by da Cunha et al.) is an arbitrary metric without clear management implications whereas the 0-50 cm diameter passage time (not reported by da Cunha et al.) represents a first-cut approximation of the sustainable cutting cycle length. 0-50 cm diameter passage times reported in other studies indicate that current Brazilian harvest regulations employ cutting cycles (25-35 years) too short for these slow-growing species. 30-50 cm diameter passage times reported by da Cunha et al. are nearly identical to those reported in these other studies, thereby indirectly validating the results and conclusions of these studies.

	Mean (min-max) passage times (yr)	
Species and source*	**30-50 cm diam**	**0-50 cm diam**
Swietenia macrophylla		
da Cunha et al. 2016 - CPI 1 trees	22 (13-105)	---
da Cunha et al. 2016 - CPI 2 trees	37 (23-103)	---
Dünisch et al. 2003 - Brazil, tree rings	30.0 (16-45)	83.7 (57-110)
Free et al. 2014 - Brazil, growth model	23.7 (7-84)	66.1 (28-159)
Cedrela odorata		
da Cunha et al. 2016 - CPI 1 trees	17 (13-27)	---
da Cunha et al. 2016 - CPI 2 trees	19 (15-25)	---
da Cunha et al. 2016 - CPI 3 trees	36 (25-57)	---
Brienen and Zuidema 2006b - Bolivia, tree rings	23.5 (9-71)	81.4 (37-152)
Amburana cearensis		
da Cunha et al. 2016 - CPI 1 trees	25 (21-34)	---
da Cunha et al. 2016 - CPI 2 trees	36 (27-52)	---
Brienen and Zuidema 2006b - Bolivia, tree rings	31.9 (25-41)	95 (61–135)
Copaifera paupera		
da Cunha et al. 2016 - CPI 1 trees	28 (22-40)	---
da Cunha et al. 2016 - CPI 2 trees	37 (23-103)	---
No other studies available	---	---

* CPI (crown position index) is a measure of light environment where values indicate (1) direct light from above and laterally; (2) direct light from above; and (3) no direct light.